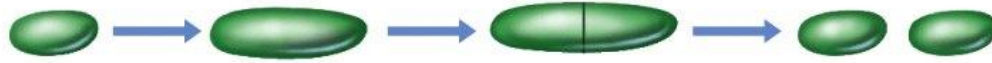


Деление клеток прокариот



Лекція 3/Молекулярні механізми
міжклітинної комунікації

I. Equal products of cell division:



Binary fission: conventional bacteria

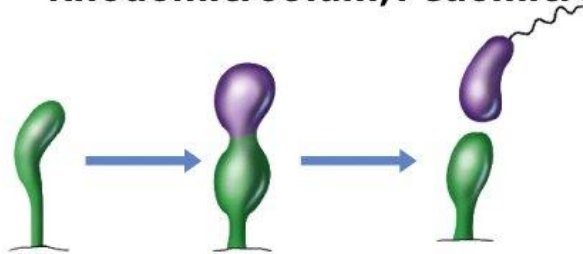
II. Unequal products of cell division:



1. Simple budding: *Pirella*, *Blastobacter*



2. Budding from hyphae: *Hyphomicrobium*, *Rhodomicrobium*, *Pedomicrobium*



3. Cell division of stalked organism: *Caulobacter*

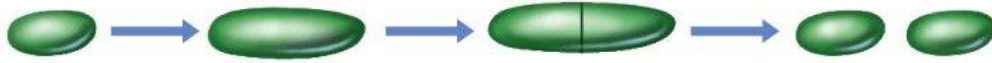


4. Polar growth without differentiation of cell size: *Rhodopseudomonas*, *Nitrobacter*, *Methylosinus*

Виды деления:

- простое деление (одинаковые дочерние клетки),
- простое почкование,
- почкование через образование выроста (гифа),
- деление стебельковой (прикрепленной) клетки,
- полярное деление без различия в размере дочерних клеток

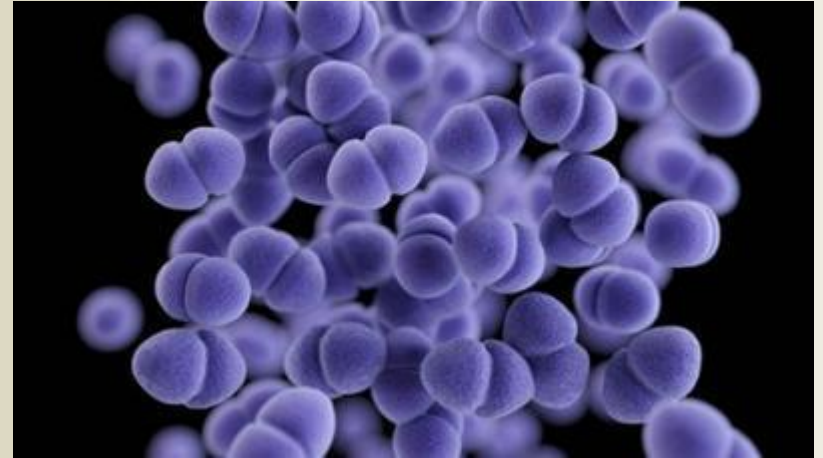
I. Equal products of cell division:



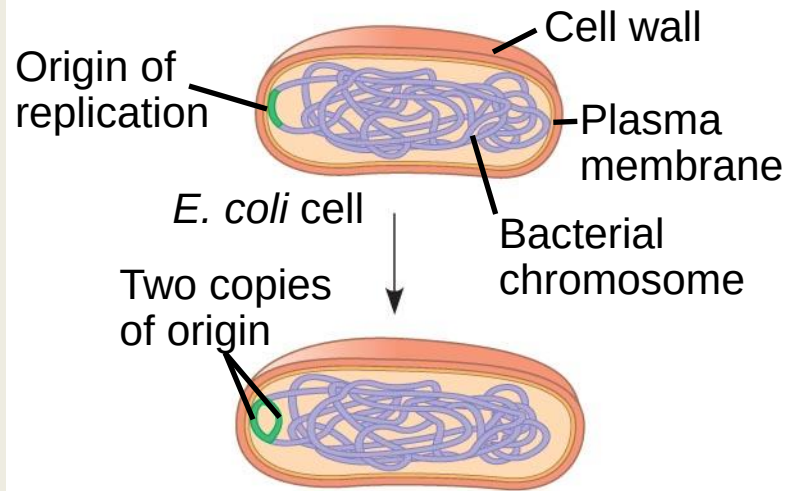
Binary fission: conventional bacteria

Виды деления:

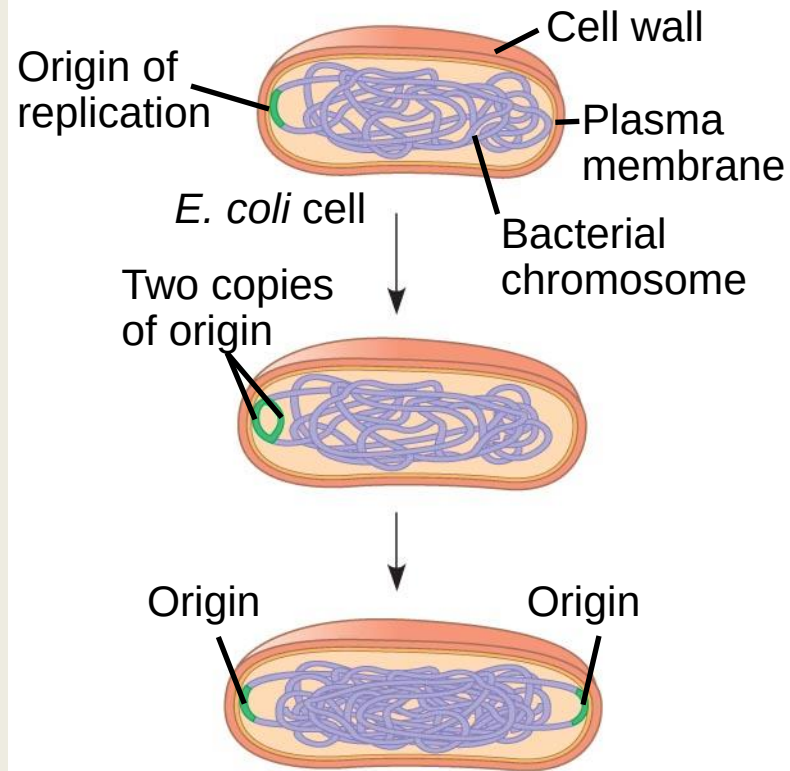
- простое деление
(одинаковые дочерние
клетки)



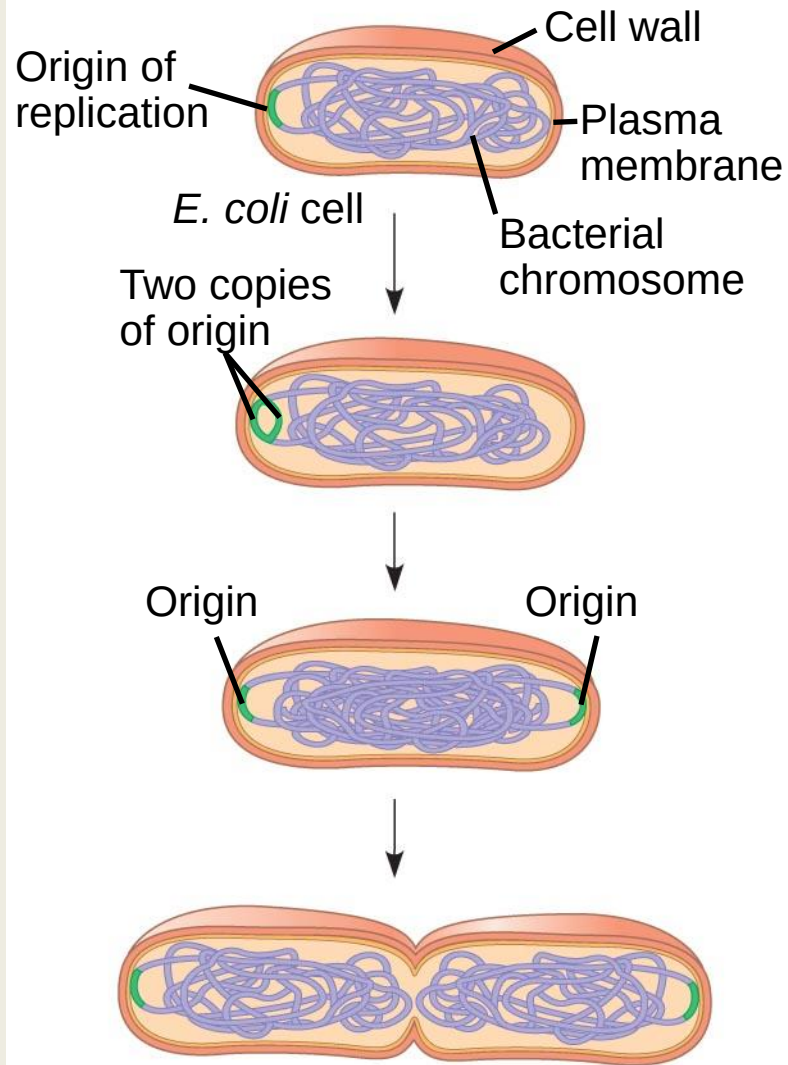
http://www.science20.com/news_articles/zombie_bacteria_invasion_nothing_to_worry_about-143654



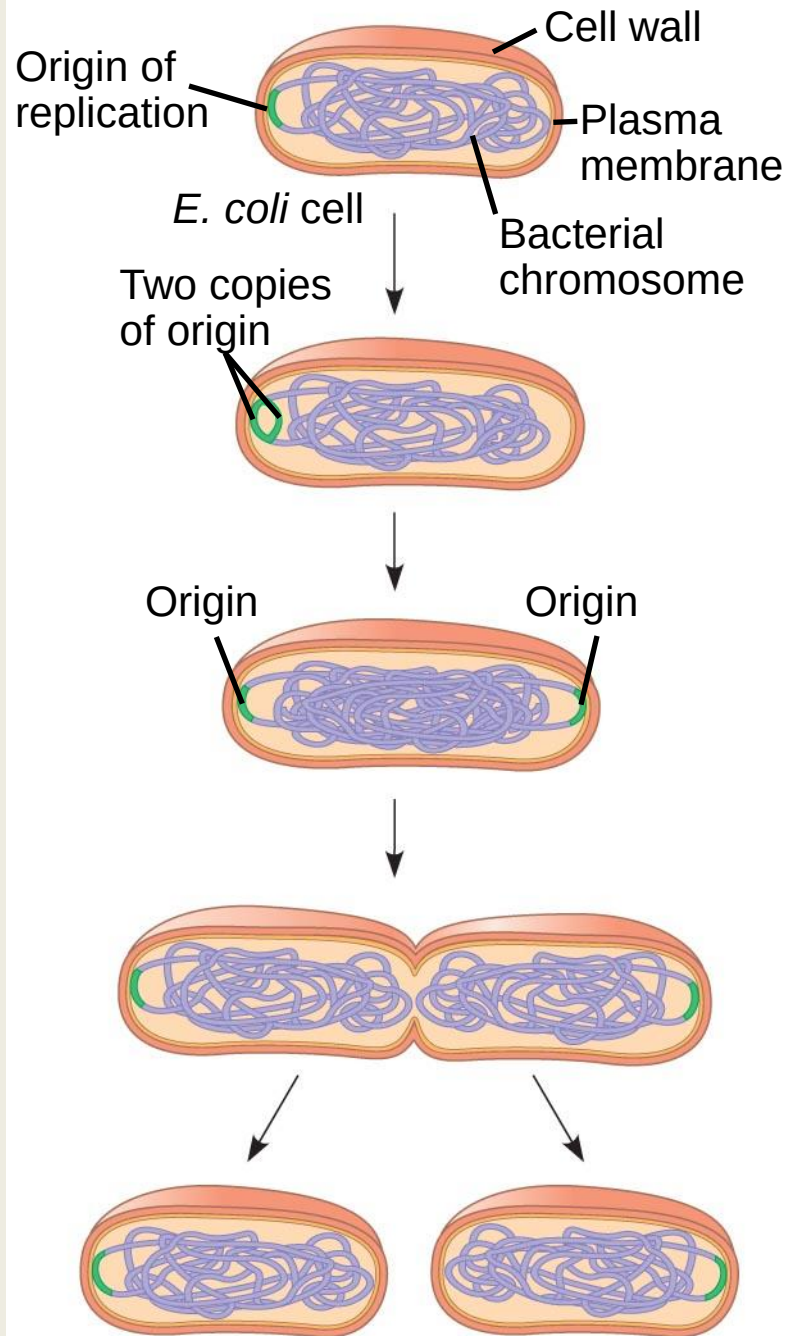
Binary Fission



Binary Fission



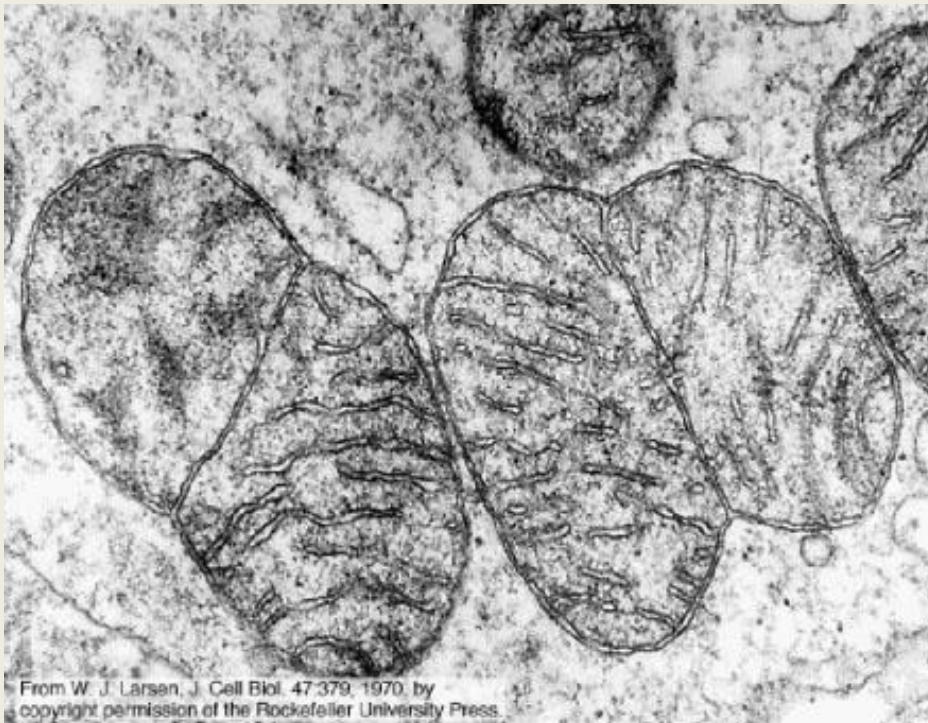
Binary Fission



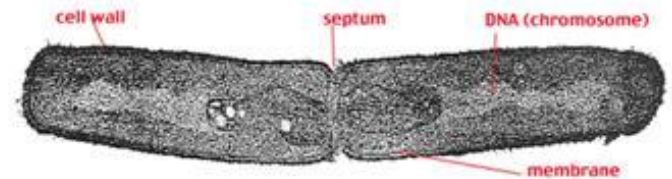
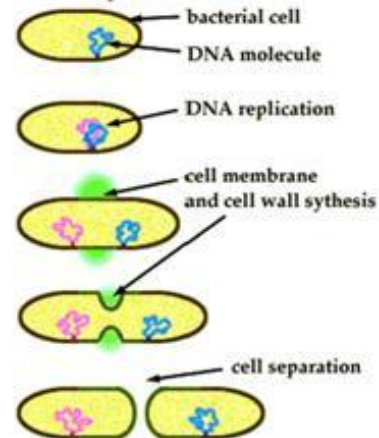
Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

Binary Fission

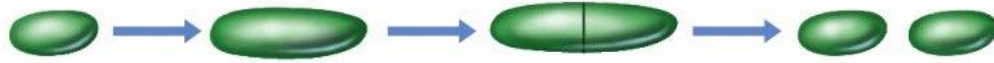
Dividing Mitochondria



Bacterial cell: Binary Fission



I. Equal products of cell division:



Binary fission: conventional bacteria

II. Unequal products of cell division:

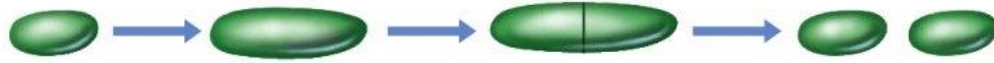


1. Simple budding: *Pirella*, *Blastobacter*

Виды деления:

- простое деление (одинаковые дочерние клетки),
- простое почкование

I. Equal products of cell division:



Binary fission: conventional bacteria

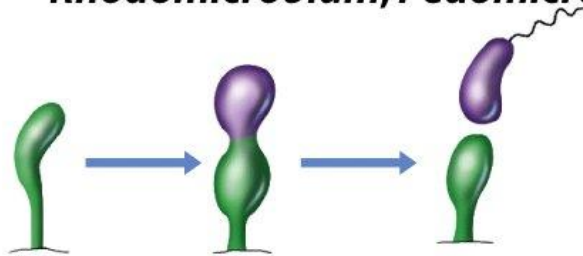
II. Unequal products of cell division:



1. Simple budding: *Pirella*, *Blastobacter*



2. Budding from hyphae: *Hyphomicrobium*, *Rhodomicrobium*, *Pedomicrobium*



3. Cell division of stalked organism: *Caulobacter*

Виды деления:

- простое деление (одинаковые дочерние клетки),
- простое почкование,
- почкование через образование выроста (гифа),
- деление стебельковой (прикрепленной) клетки

the contrast between cell division in conventional bacteria and in budding and stalked bacteria

- Two well-studied budding bacteria are closely related phylogenetically: *Hyphomicrobium*, which is chemoorganotrophic, and *Rhodomicrobium*, which is phototrophic. These organisms release buds from the ends of long, thin hyphae.
- The hypha is a direct cellular extension of the mother cell and contains cell wall; cytoplasmic membrane; ribosomes; and, occasionally, DNA.

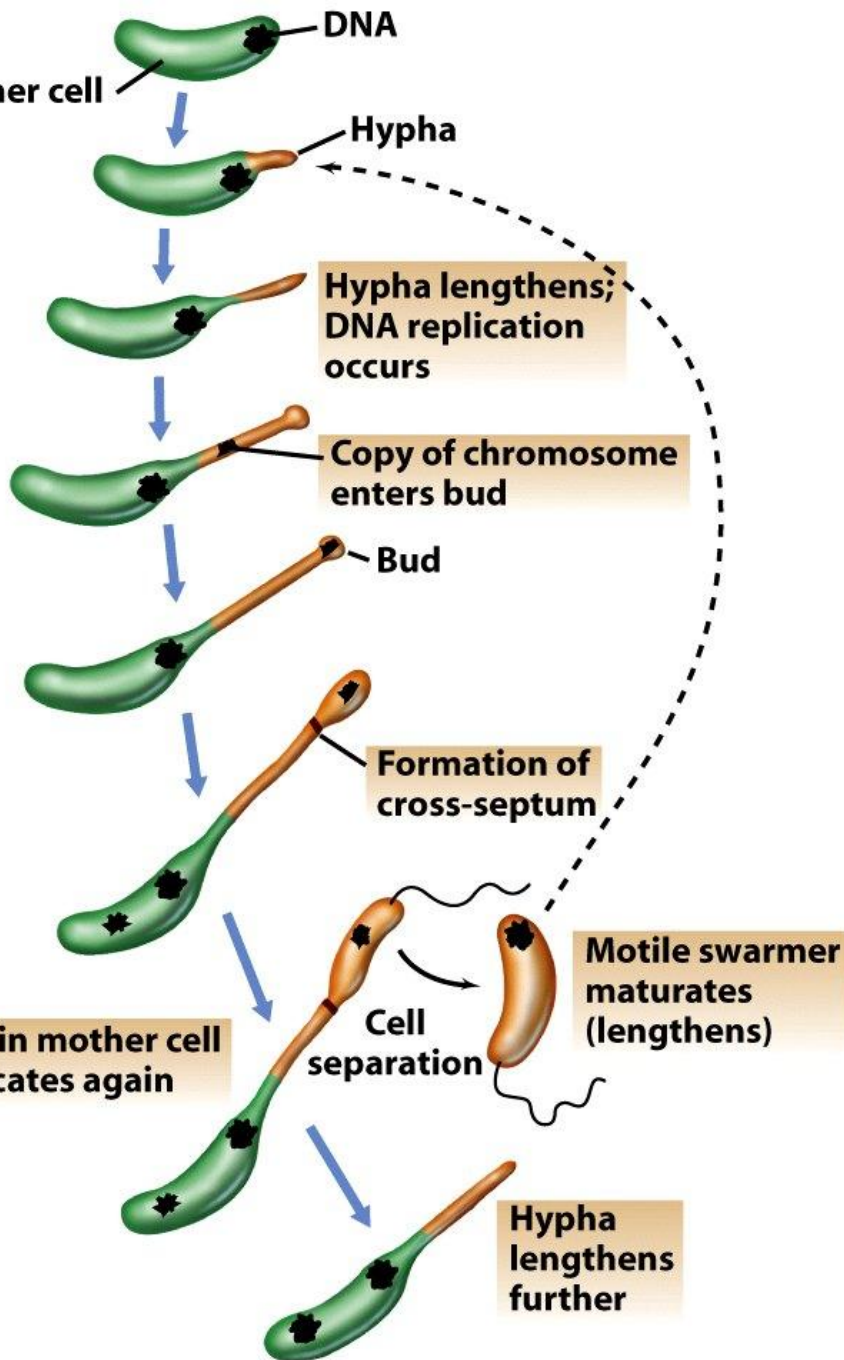


Figure 12-39 Brock Biology of Microorganisms 11/e
© 2006 Pearson Prentice Hall, Inc.

Stalked
Cell

Flagellum

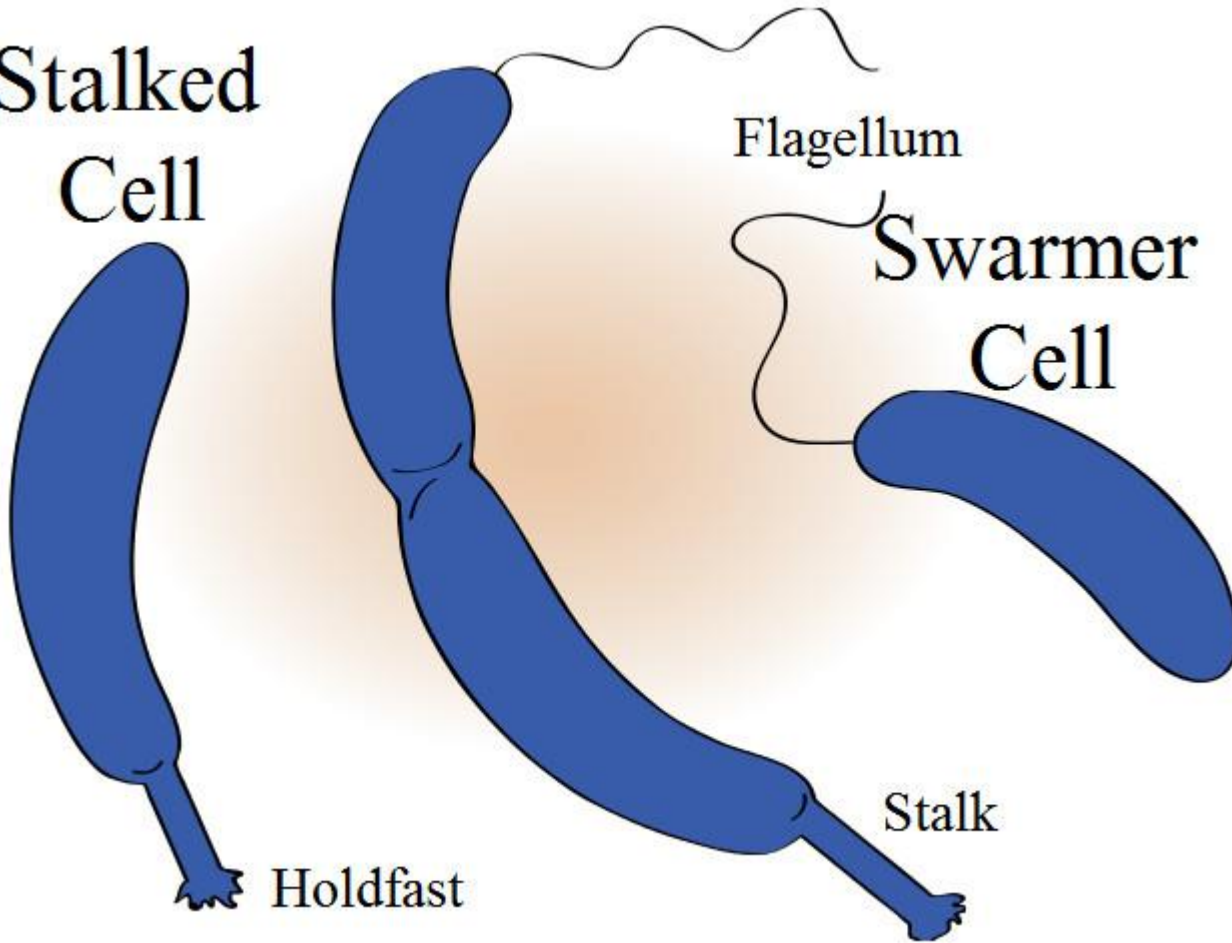
Swarmer
Cell

Stalk

Holdfast

One common stalked bacterium is *Caulobacter*.

Stages in the *Caulobacter* cell cycle beginning with a swarmer cell.



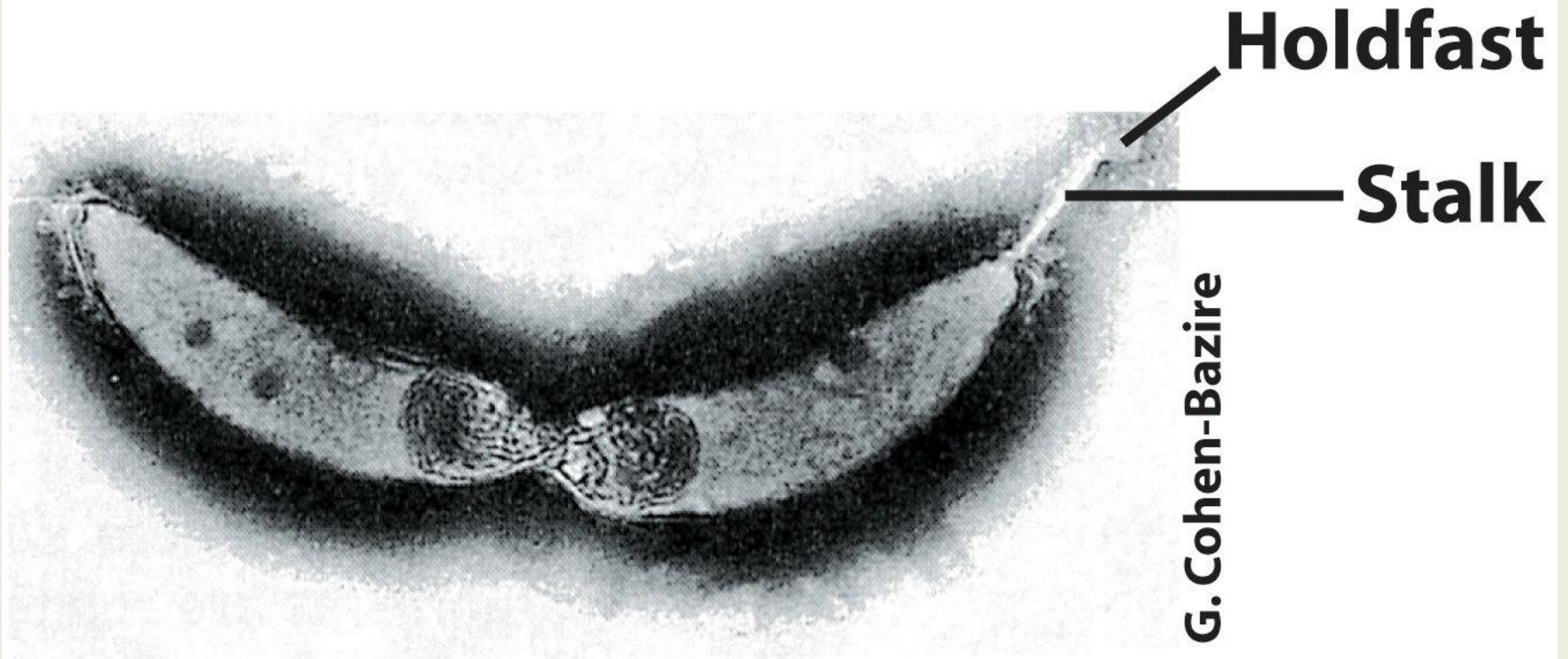
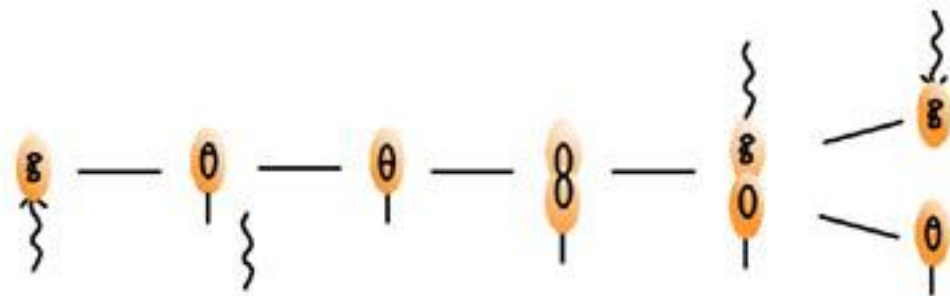
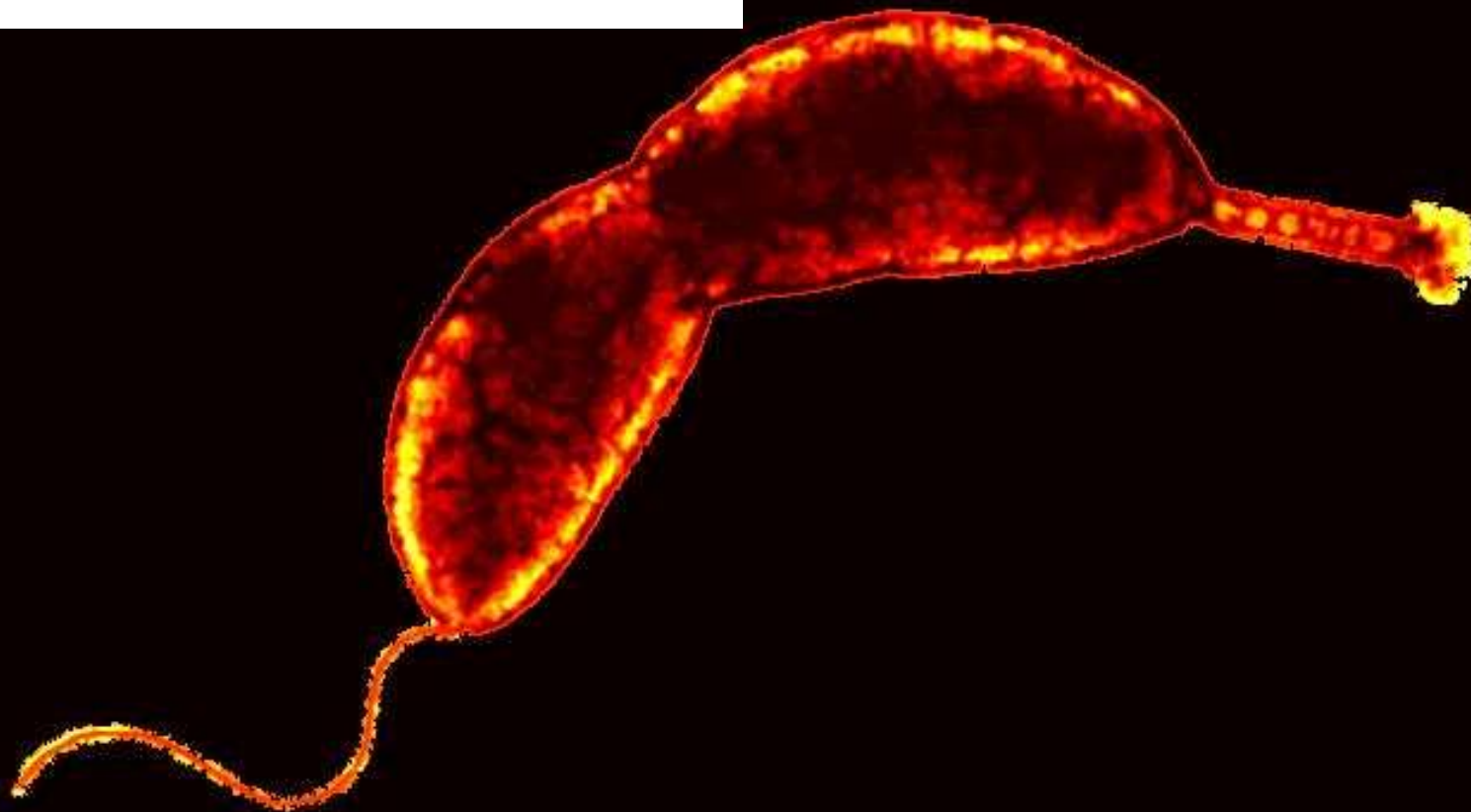


Figure 12-41b Brock Biology of Microorganisms 11/e
© 2006 Pearson Prentice Hall, Inc.



Caulobacter crescentus



Caulobacter crescentus

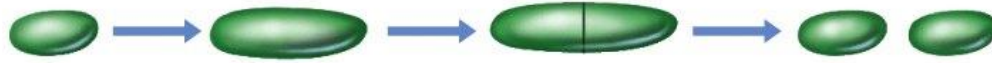


Stalk

G. Cohen-Bazire

Figure 12-41c Brock Biology of Microorganisms 11/e
© 2006 Pearson Prentice Hall, Inc.

I. Equal products of cell division:



Binary fission: conventional bacteria

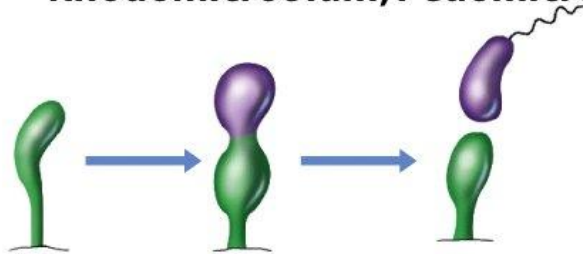
II. Unequal products of cell division:



1. Simple budding: *Pirella*, *Blastobacter*



2. Budding from hyphae: *Hyphomicrobium*, *Rhodomicrobium*, *Pedomicrobium*



3. Cell division of stalked organism: *Caulobacter*



4. Polar growth without differentiation of cell size: *Rhodopseudomonas*, *Nitrobacter*, *Methylosinus*

Виды деления:

- простое деление (одинаковые дочерние клетки),
- простое почкование,
- почкование через образование выроста (гифа),
- деление стебельковой (прикрепленной) клетки,
- полярное деление без различия в размере дочерних клеток

the contrast between cell division in conventional bacteria and in budding and stalked bacteria

Gliding Myxobacteria

- The fruiting myxobacteria are rod-shaped, gliding bacteria that aggregate to form complex masses of cells called fruiting bodies. Myxobacteria are chemoorganotrophic soil bacteria that live by consuming dead organic matter or other bacterial cells.

Table 12.20**Classification of the fruiting myxobacteria^a**

Characteristics	Genus/DNA (mol% GC)
Vegetative cells tapered:	
Spherical or oval myxospores, fruiting bodies usually soft and slimy without well-defined sporangia or stalks	<i>Myxococcus</i> (68–71)
Rod-shaped myxospores:	
Myxospores not contained in sporangia, fruiting bodies without stalks	<i>Archangium</i> (67–68)
Myxospores embedded in slime envelope:	
Fruiting bodies without stalks	<i>Cystobacter</i> (68)
Stalked fruiting bodies, single sporangia	<i>Melittangium</i> (—)
Stalked fruiting bodies, multiple sporangia	<i>Stigmatella</i> (68–69)
Fruiting bodies are dark-brown clusters consisting of tiny spherical or disclike sporangia with an outer wall	<i>Angiococcus</i> (—)

^a Phylogenetically, those species examined fall into the delta subdivision of the Proteobacteria (see Table 12.1).

Table 12.20**Classification of the fruiting
myxobacteria^a****Characteristics****Genus/DNA
(mol% GC)**

**Vegetative cells not tapered
(blunt, rounded ends); myxospores
resemble vegetative cells; sporangia
always produced:**

Fruiting bodies without stalks;
myxospores rod-shaped

Polyangium (69)

Fruiting bodies without stalks;
myxospores oval; highly cellulolytic

Sorangium (—)

Fruiting bodies without stalks;
myxospores coccoid

Nannocystis (70–72)

Stalked fruiting bodies

Chondromyces (69–70)

^a Phylogenetically, those species examined fall into the delta subdivision of the Proteobacteria (see Table 12.1).

The life cycle of a typical fruiting myxobacterium

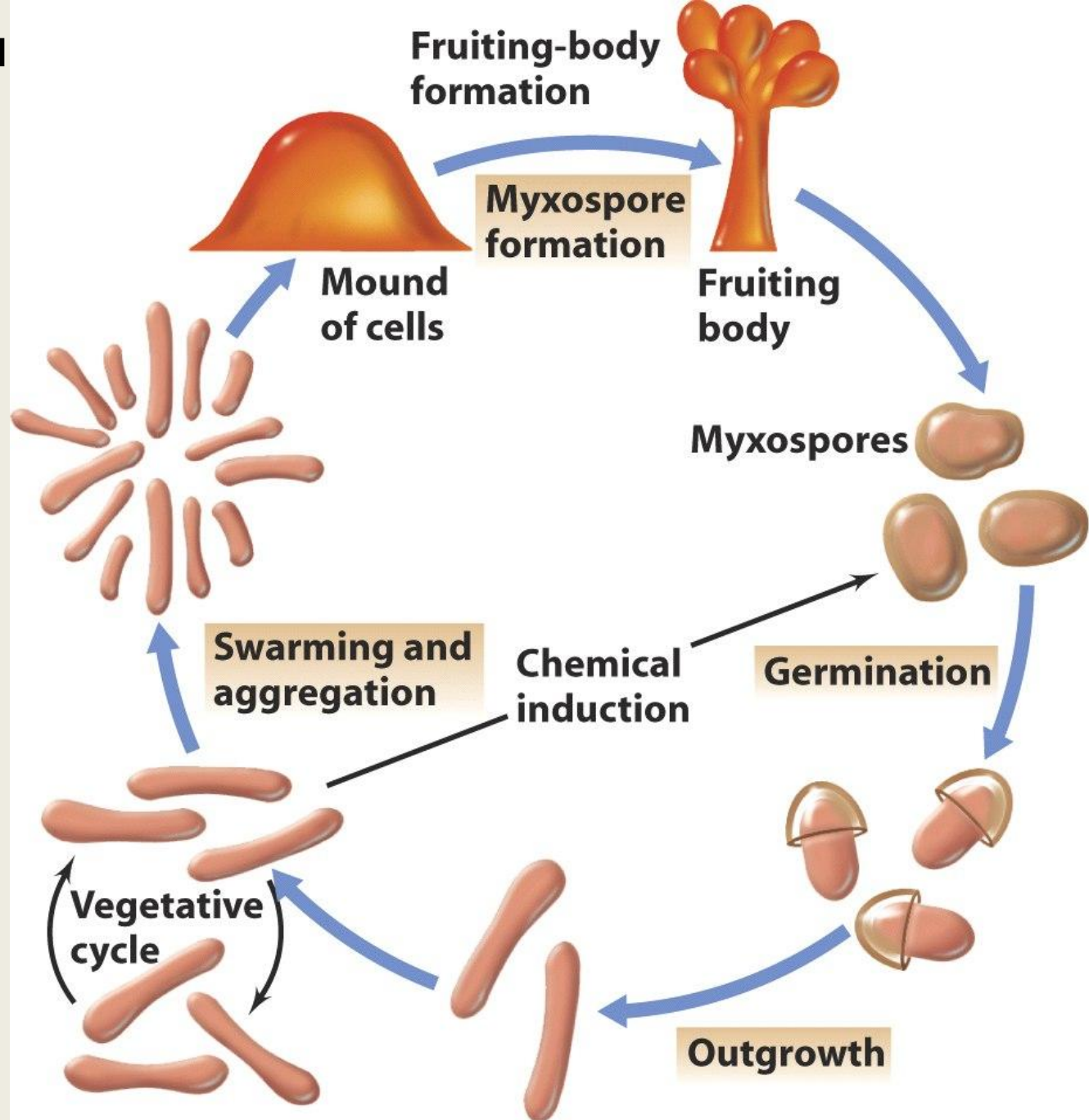
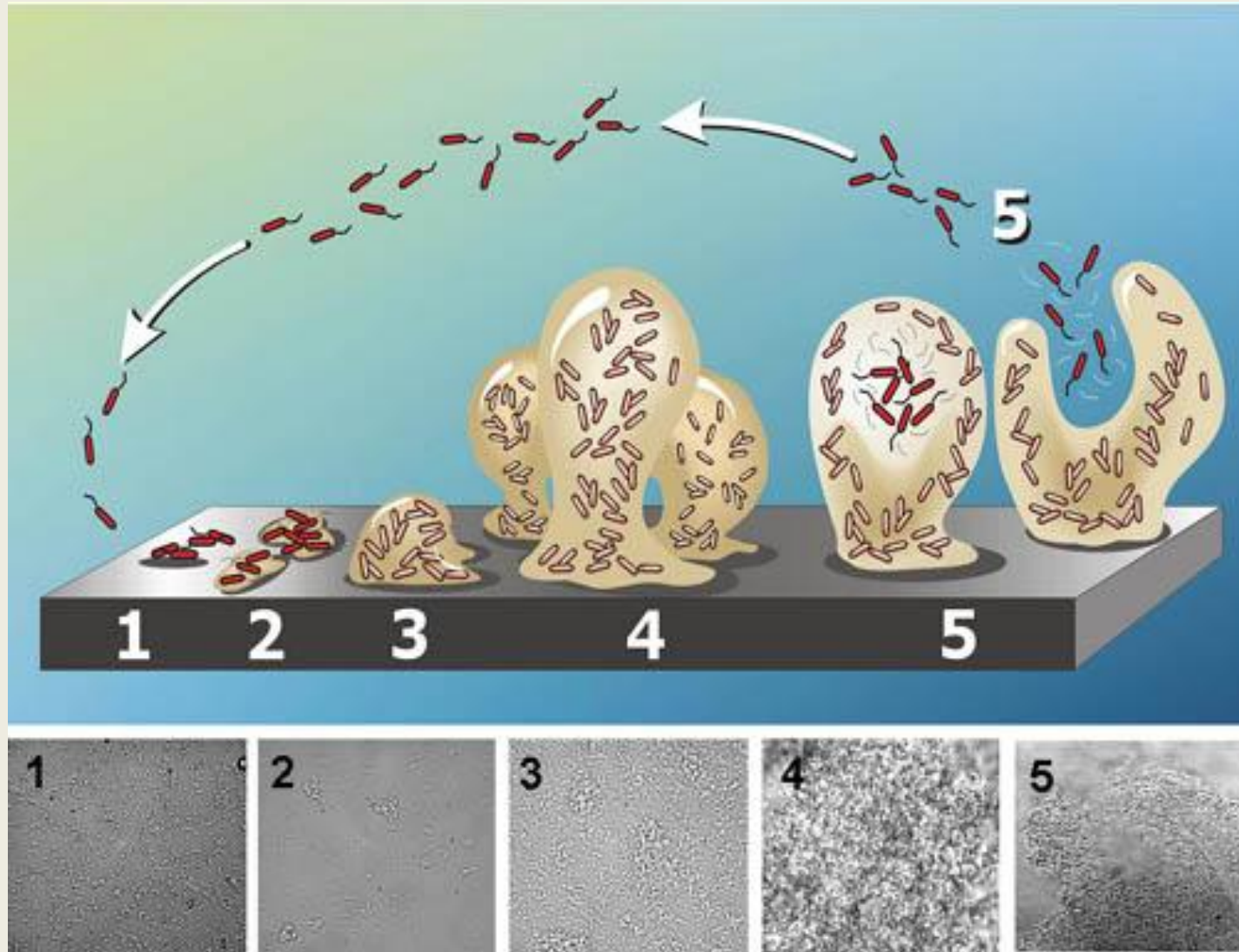


Figure 12-47 Brock Biology of Microorganisms 11/e
© 2006 Pearson Prentice Hall, Inc.

Steps in Biofilm Formation



Размеры бактериальных клеток

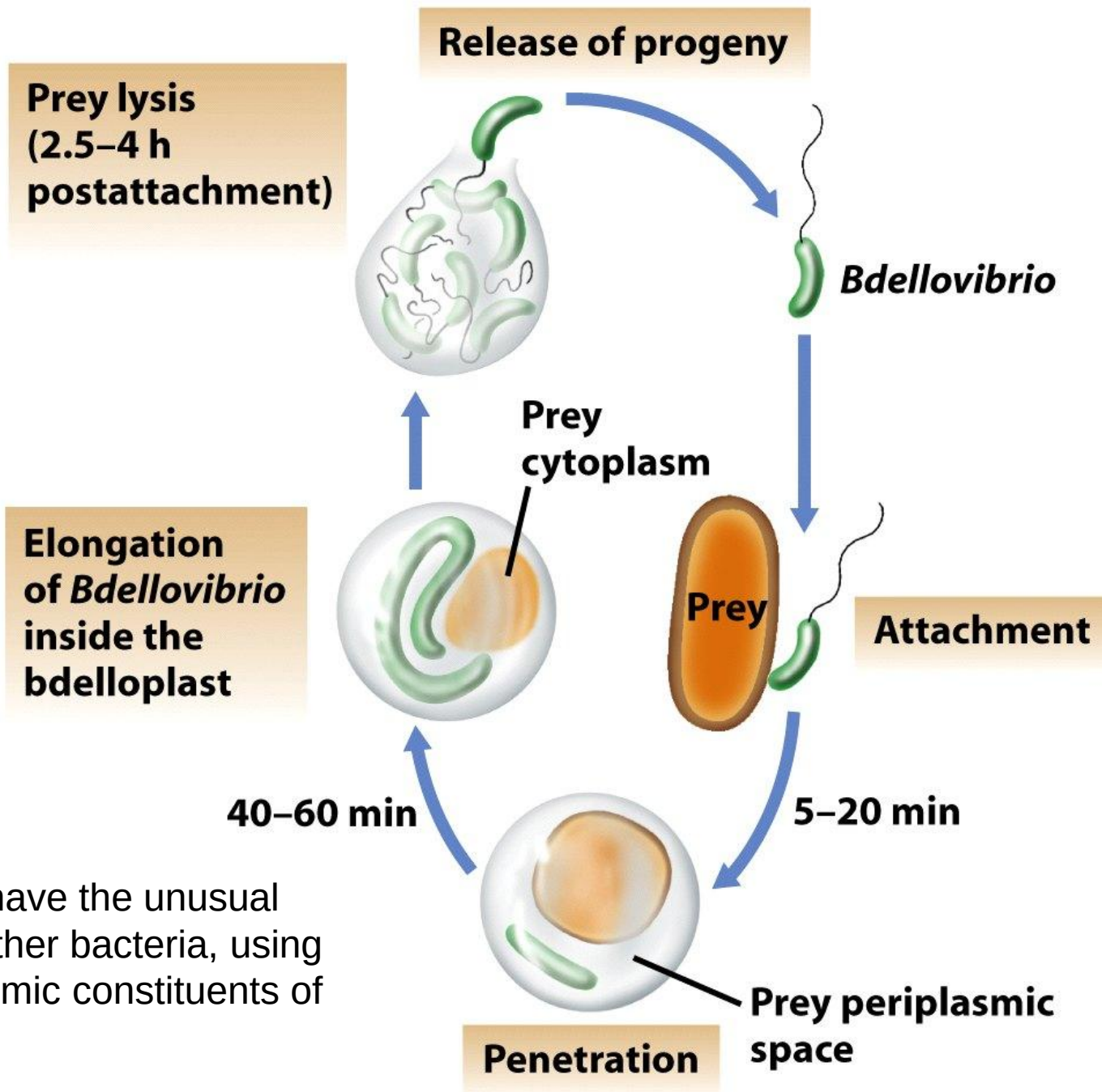
Table 12.18 Characteristics of the genera of spiral-shaped bacteria^a

Genus	Phylogenetic group ^b	Characteristics	DNA (mol % GC)
<i>Spirillum</i>	Beta	<u>Cell diameter 1.7 μm; microaerophilic; freshwater</u>	36–38
<i>Aquaspirillum</i>	Alpha or beta	Cell diameter 0.2–1.5 μm ; aerobic; freshwater	49–66
<i>Magnetospirillum</i>	Alpha	Vibrio to spirillum-shaped; cell diameter about 0.3 μm ; contains magnetosomes; microaerophilic	65
<i>Oceanospirillum</i>	Gamma	Cell diameter 0.3–1.2 μm ; aerobic; marine (require 3% NaCl)	42–51
<i>Azospirillum</i>	Alpha	Cell diameter 1 μm ; microaerophilic; soil and rhizosphere; fixes N ₂	68–70
<i>Herbaspirillum</i>	Beta	Cell diameter 0.6–0.7 μm ; microaerophilic; soil and rhizosphere; fixes N ₂	66–67
<i>Campylobacter</i>	Epsilon	Cell diameter 0.2–0.8 μm ; microaerophilic to anaerobic; pathogenic or commensal in humans and animals; single polar flagellum	30–38
<i>Helicobacter</i>	Epsilon	Cell diameter 0.5–1 μm ; tuft of polar flagella; associated with pyloric ulcers in humans	36–38
<i>Bdellovibrio</i>	Delta	<u>Cell diameter 0.25–0.4 μm; aerobic; predatory on other bacteria; single polar sheathed flagellum</u>	33–52
<i>Ancyclobacter</i>	Alpha	Cell diameter 0.5 μm ; curved rods forming rings; nonmotile, aerobic; sometimes gas-vesiculate	66–69

^a All are gram-negative and respiratory but never fermentative.

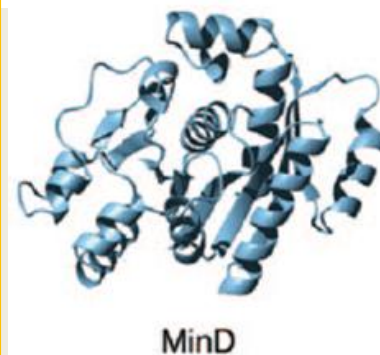
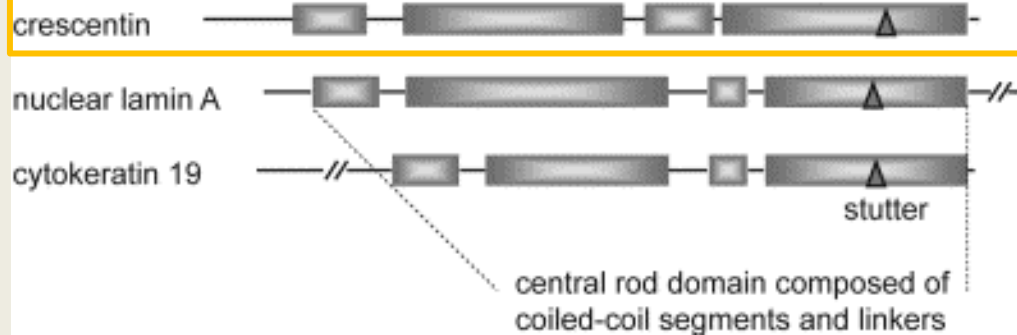
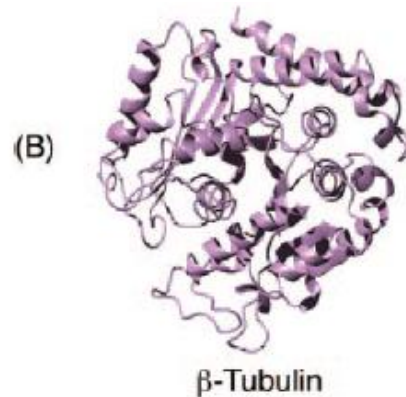
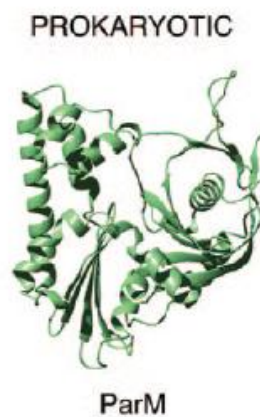
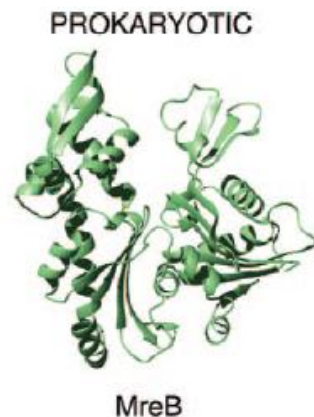
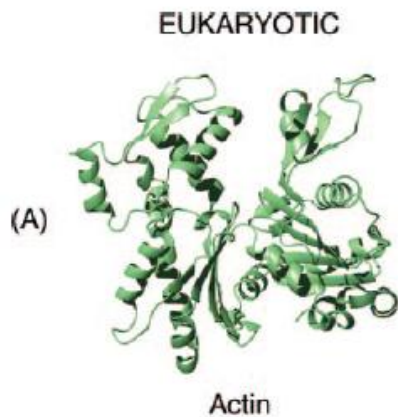
^b All are Proteobacteria.

**Bdellovibrio –
бактерия -
внутриклеточный
паразит других
бактерий**

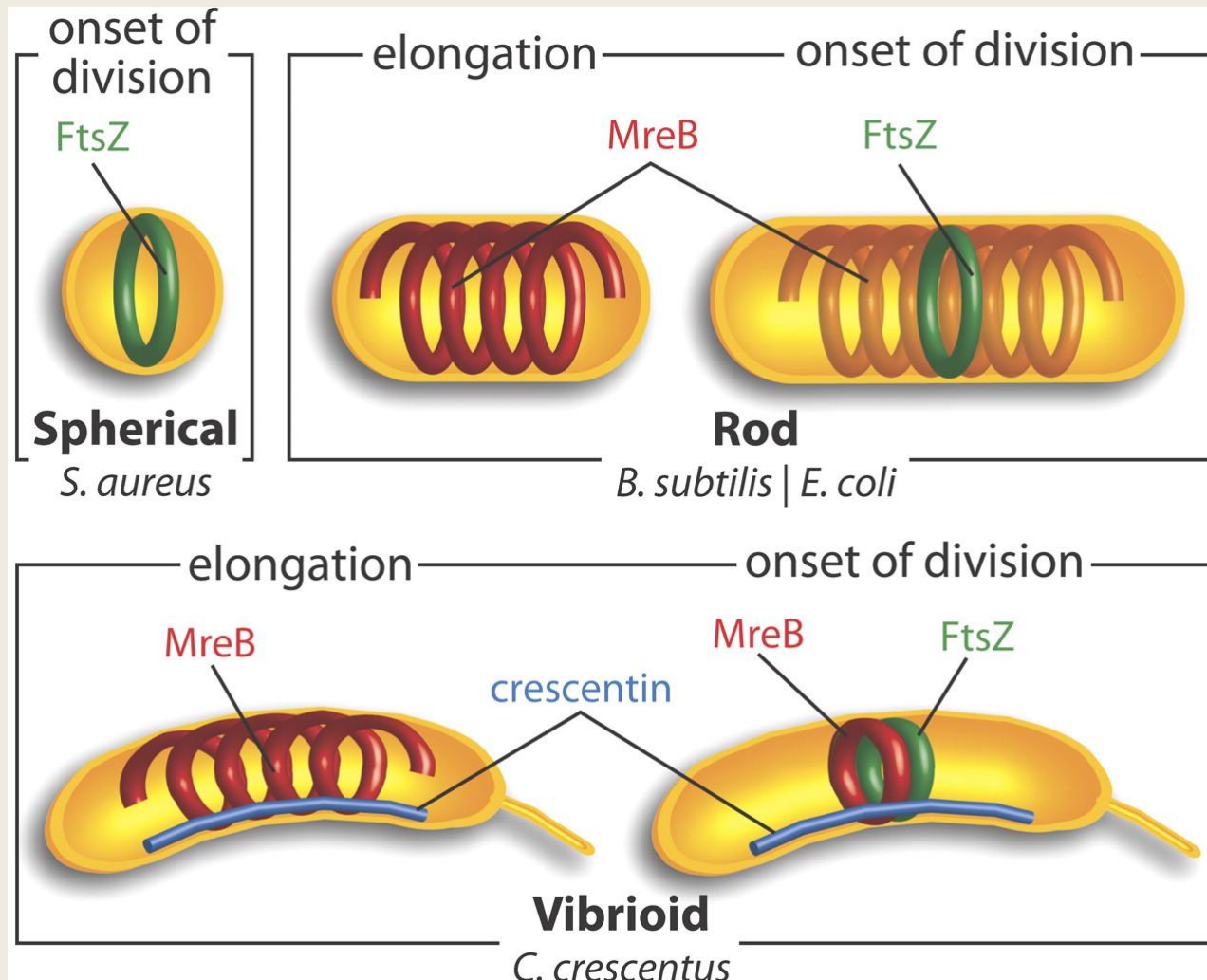


Bdellovibrio organisms have the unusual property of preying on other bacteria, using as nutrients the cytoplasmic constituents of their hosts

Роль белков цитоскелета в делении прокариот

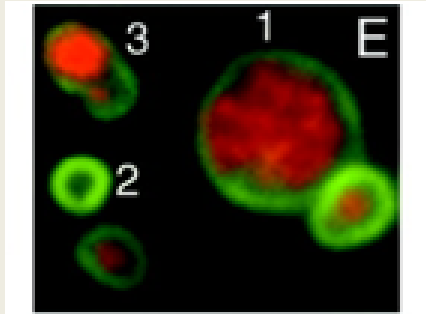


Участие актин- и тубулин-подобных белков в делении бактерий



Cabeen, Jacobs-Wagner J. Cell Biol. 2008;179:381-387

Localization and functions of the actin-like MreB protein



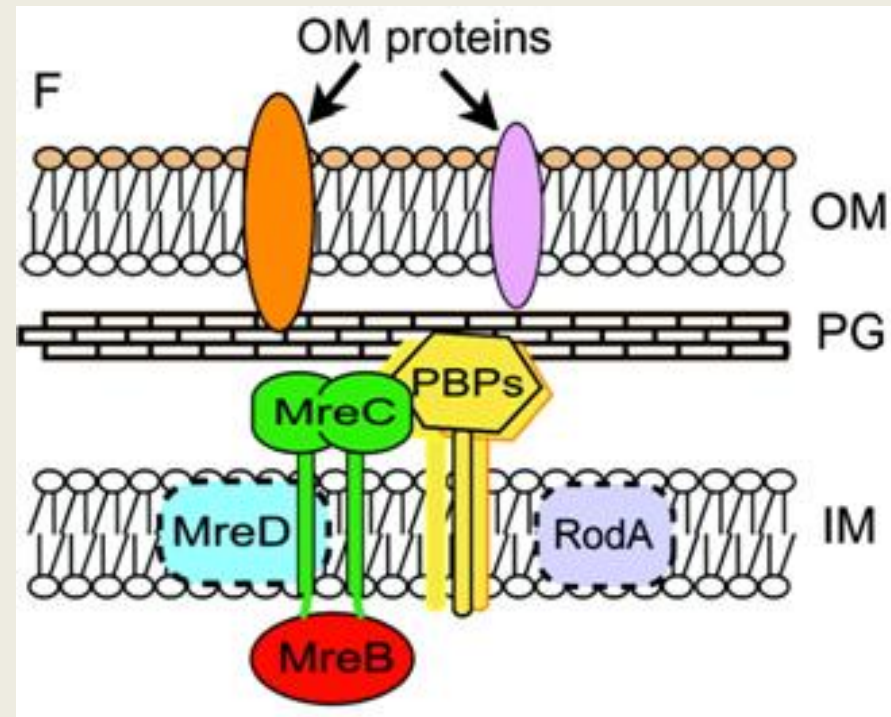
(E) Chromosome segregation in *E. coli* *mreB* deletion strain
Bacterial DNA – red /membrane - green

(F) Suggested organization of cytoskeleton-associated cell wall-synthesizing proteins of *E. coli*.

The cytoplasmic MreB cytoskeleton is linked via MreC and MreD to the PBP murein biosynthetic enzymes.

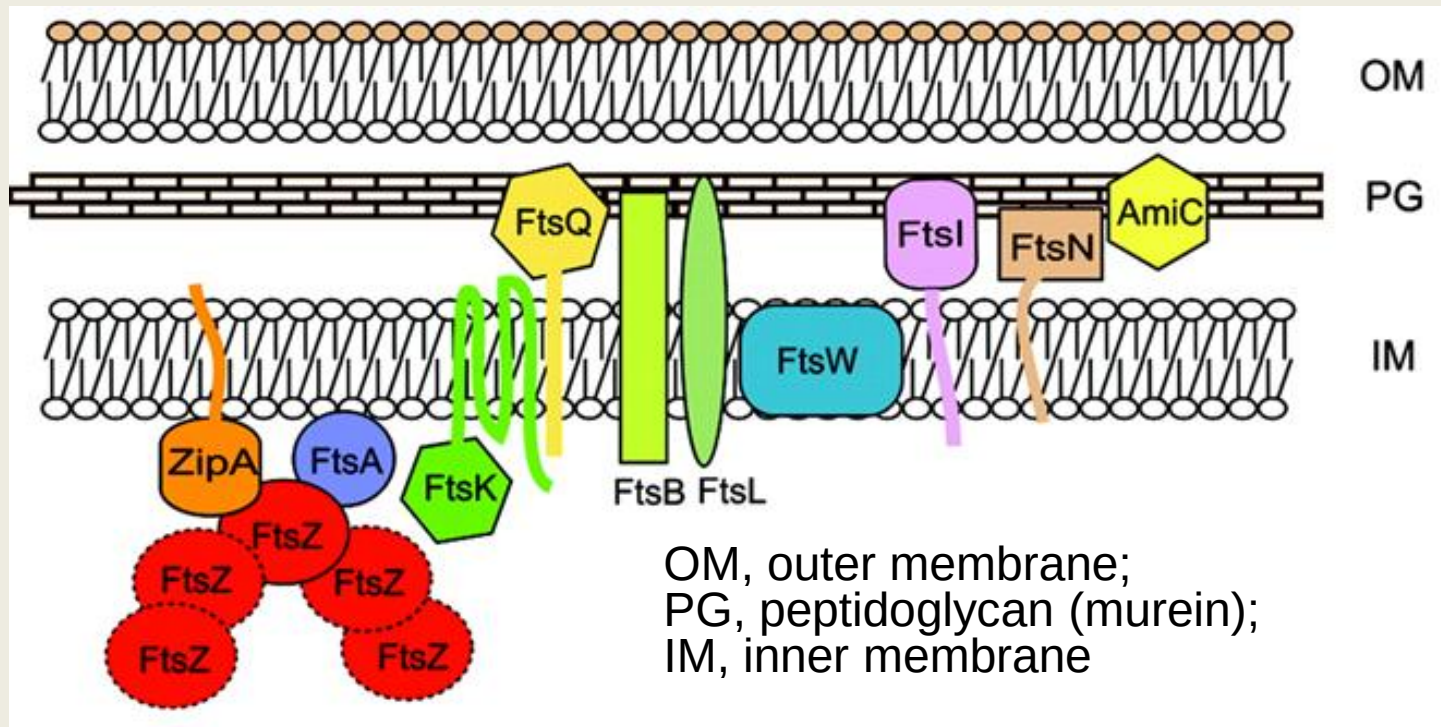
MreC is shown as a transmembrane protein, but it may be a periplasmic.

This multiprotein structure may permit the MreB cytoskeleton to regulate the pattern of cell wall biosynthesis by providing spatial information to the murein biosynthetic machinery.



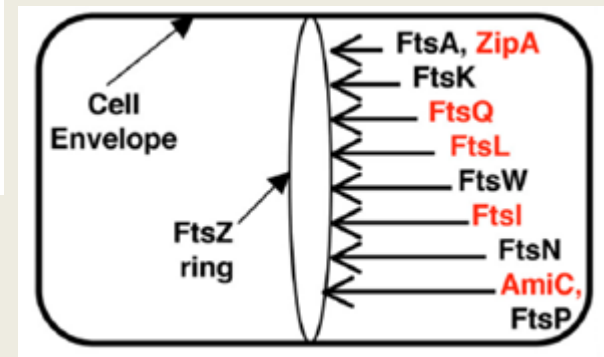
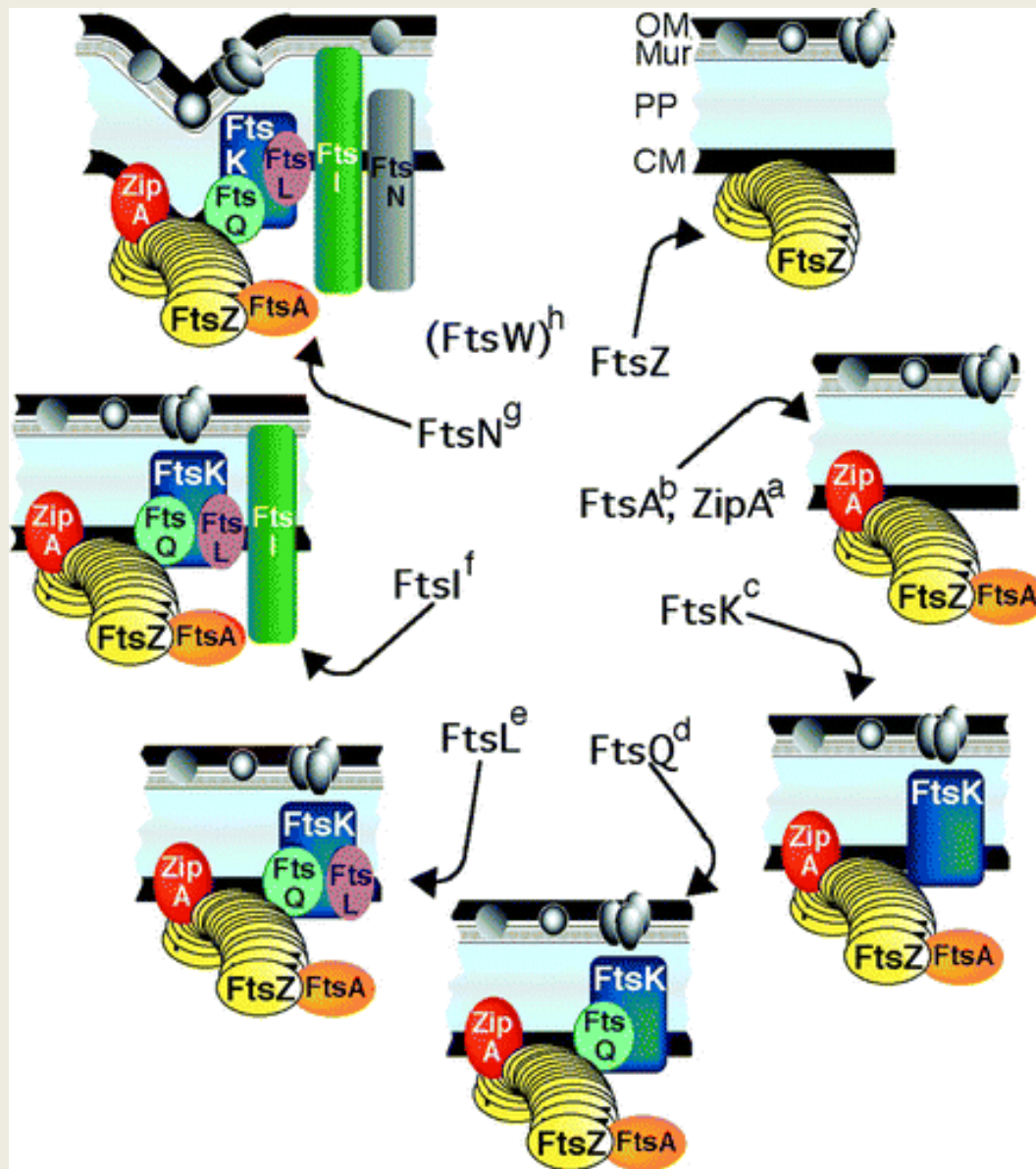
OM, outer membrane;
PG, peptidoglycan (murein);
IM, inner membrane

Diagrammatic representation of a portion of the cytokinetic ring (septasome) of *E. Coli*

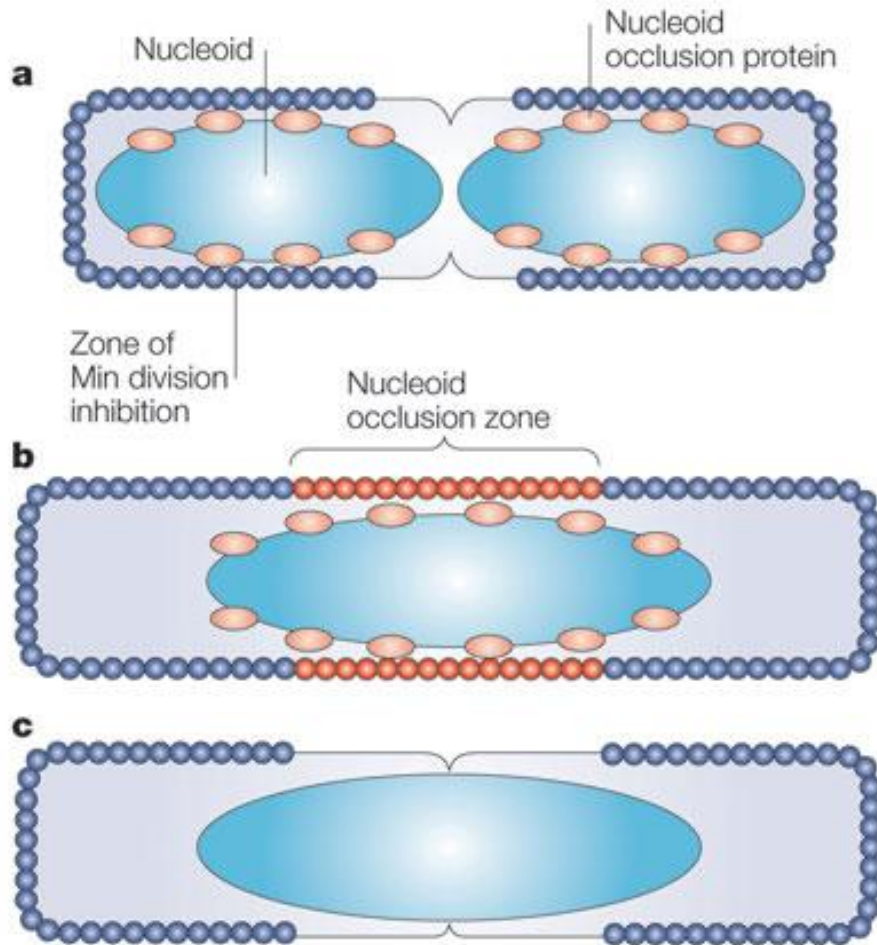


FtsZ is anchored to the cell membrane by FtsA and ZipA, and the other septasomal proteins are then added to the complex.

- Prokaryotic cell division involves formation of a complex **cytokinetic ring**



- The cell division site is determined by two negative regulatory systems: nucleoid occlusion & the Min system



Copyright © 2005 Nature Publishing Group
Nature Reviews | Microbiology

The nucleoid occlusion proteins (Noc or SlmA, light red ovals) are associated with the nucleoid.

a Under normal conditions, the **Min system** leads to a zone of **division inhibition** (blue circles) extending from the poles towards midcell. This is apparently sufficient to prevent FtsZ-ring formation and septation over the segregated daughter nucleoids.

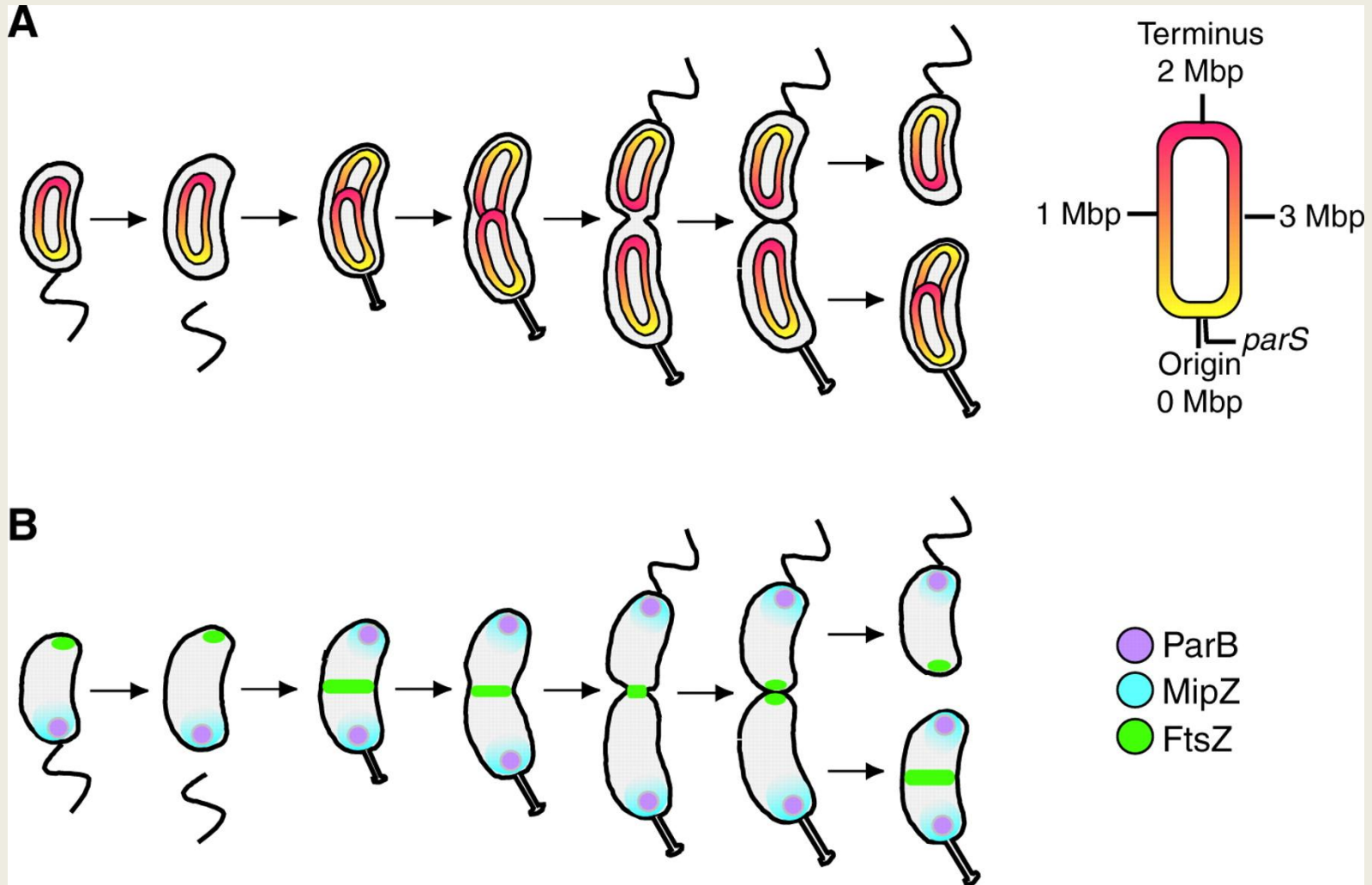
b When chromosome replication or segregation of daughter chromosomes to the ends of the cell is prevented, the nucleoid remains near midcell and the cells elongate. The nucleoid occlusion proteins (NOP) then **prevent FtsZ-ring formation** and septation over the nucleoid (red circles).

c When the NOP is absent and chromosome replication or segregation is prevented, the effect is lost. The zone of division inhibition induced by the Min system apparently does not extend far enough from the poles to prevent formation of FtsZ rings over the centrally located nucleoid.

Regulation of division in prokaryotes

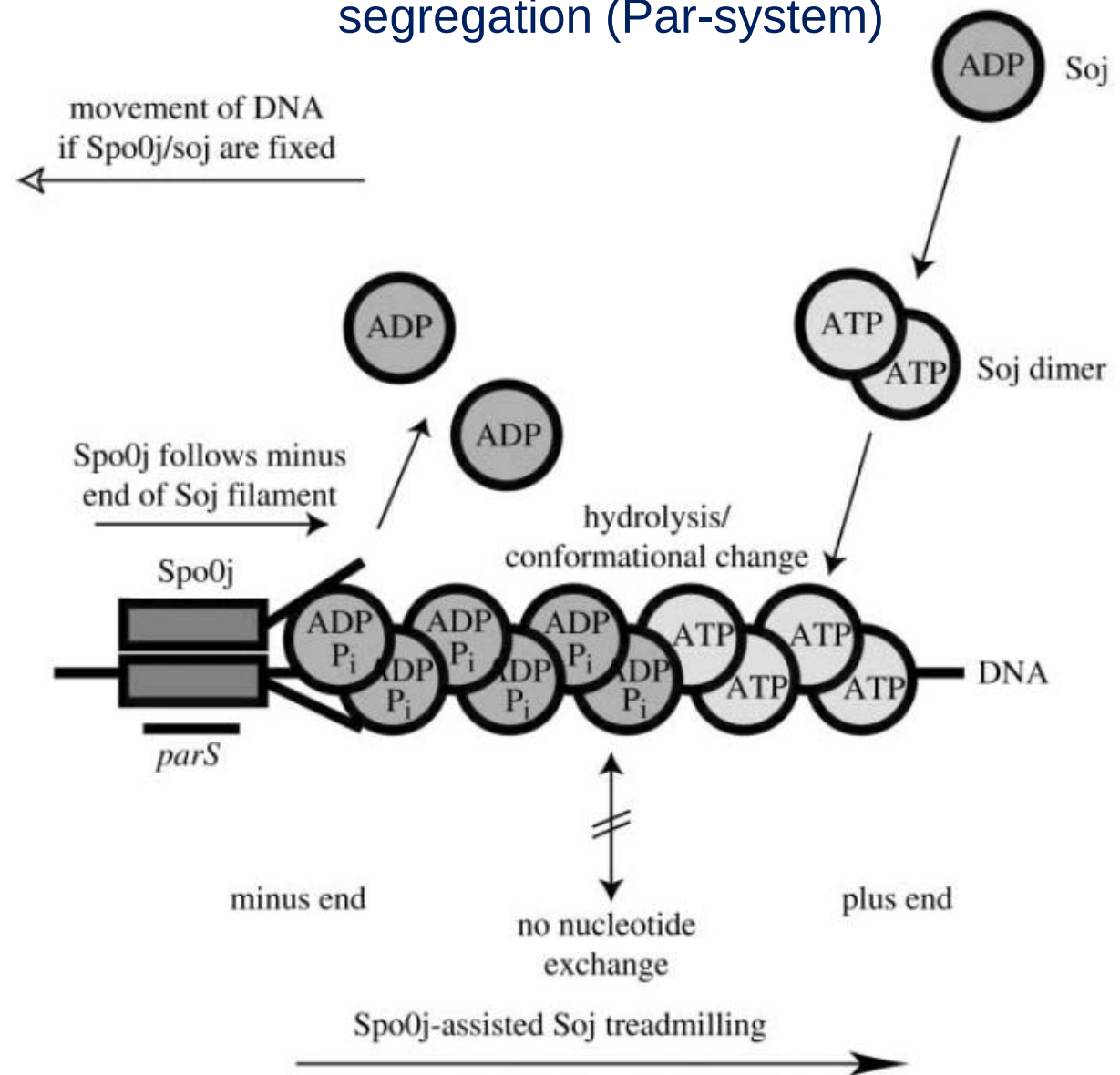
- Proper placement of the cell division site in some rod-shaped bacteria requires two different negative regulatory systems, **nucleoid occlusion and the Min proteins**.
- *Caulobacter crescentus* lacks these systems, but recent work has uncovered **a novel regulator** that achieves the same goals. Thanbichler and Shapiro discovered a protein, called MipZ, which is sufficient to promote proper Z ring targeting by integrating both spatial and cell cycle signals.
- Depletion of MipZ resulted in a phenotype reminiscent of inactivating Min proteins in *E. coli*, but more severe: cells divided much less frequently and became filamentous, and often divided at inappropriate locations such as cell poles to create minicells.
- Overproduction of MipZ had an effect similar to overproduction of MinCD, in that cells continued to grow and segregate their chromosomes, but failed to form Z rings, generating long filaments.
- From **Bacterial Division: Another Way to Box in the Ring**, 2006

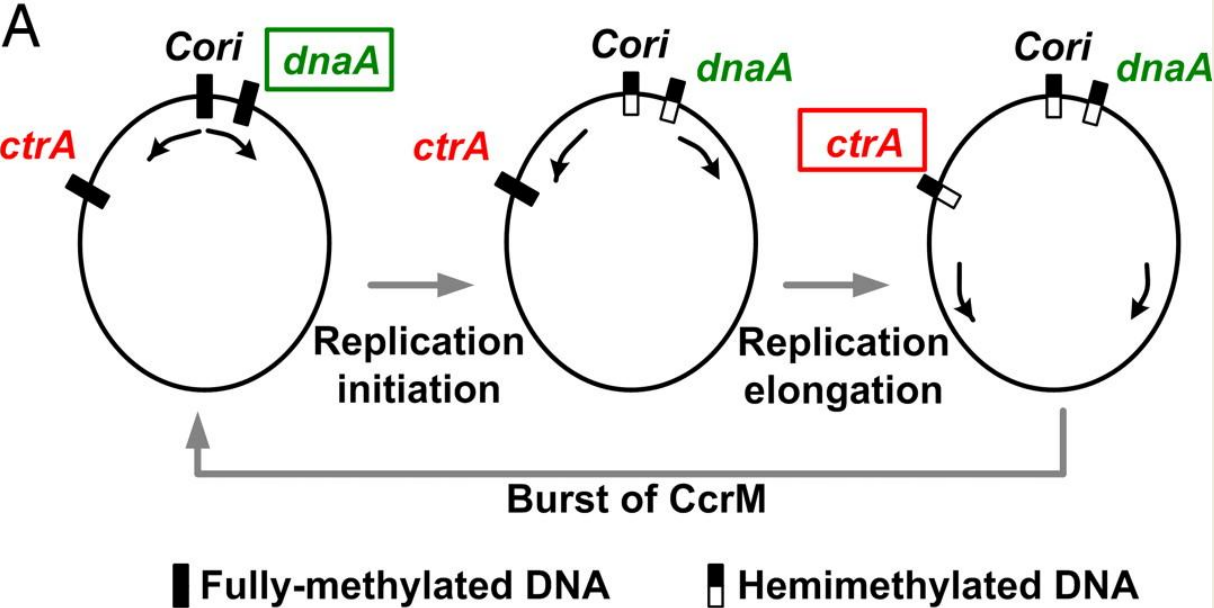
Chromosome organization and division site specification.



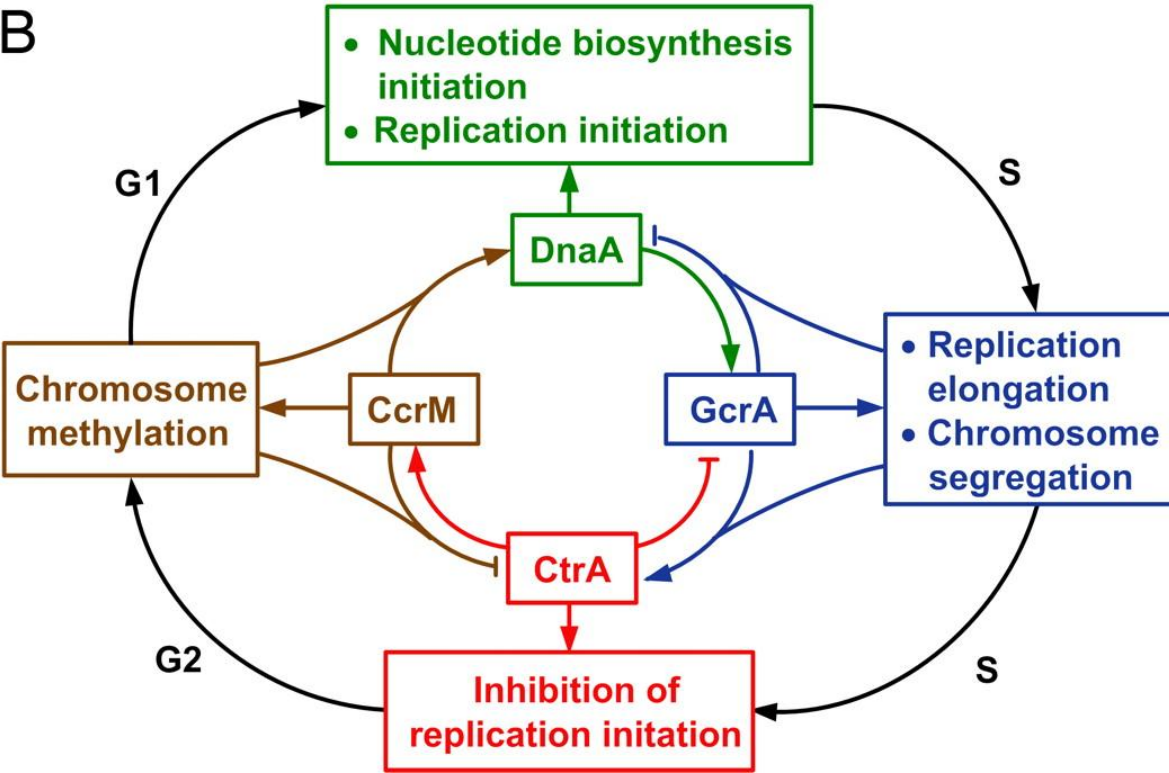
Goley E D et al. J Cell Sci 2007;120:3501-3507

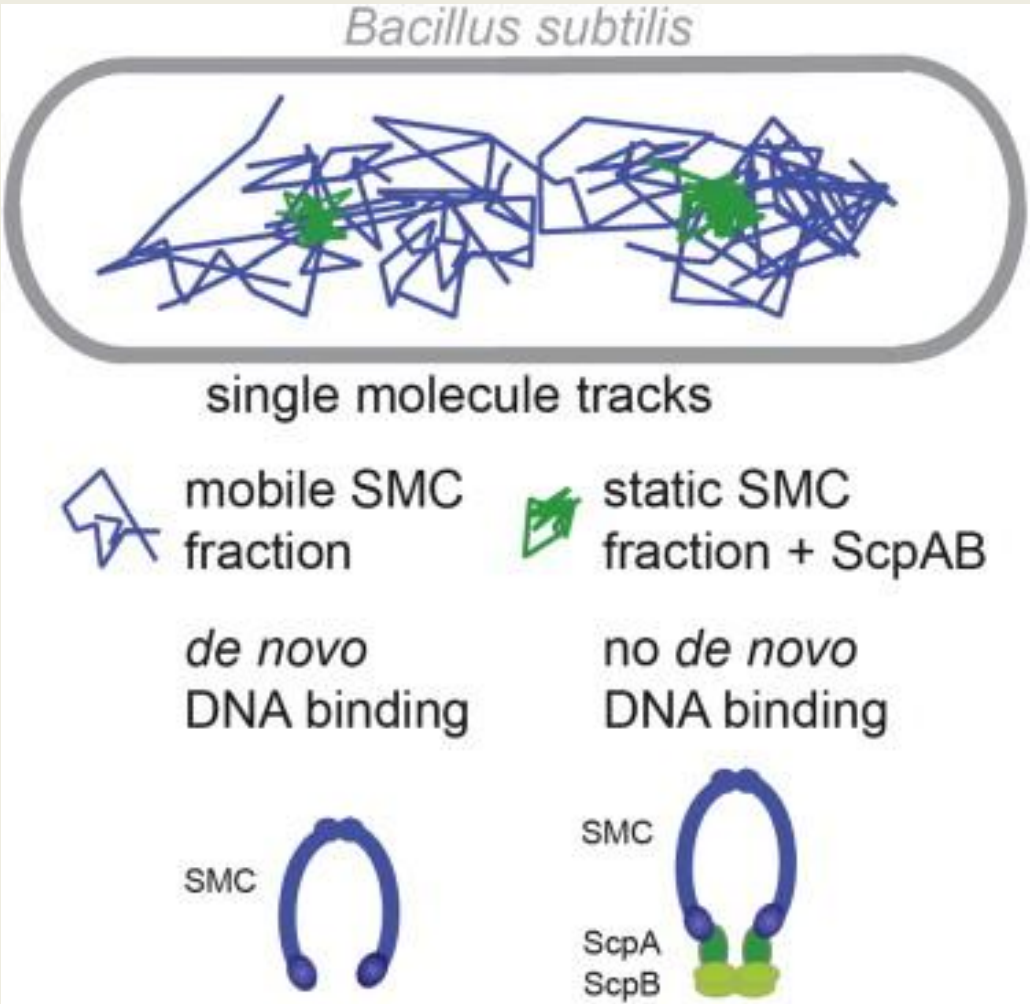
- Control of chromosome segregation (Par-system)



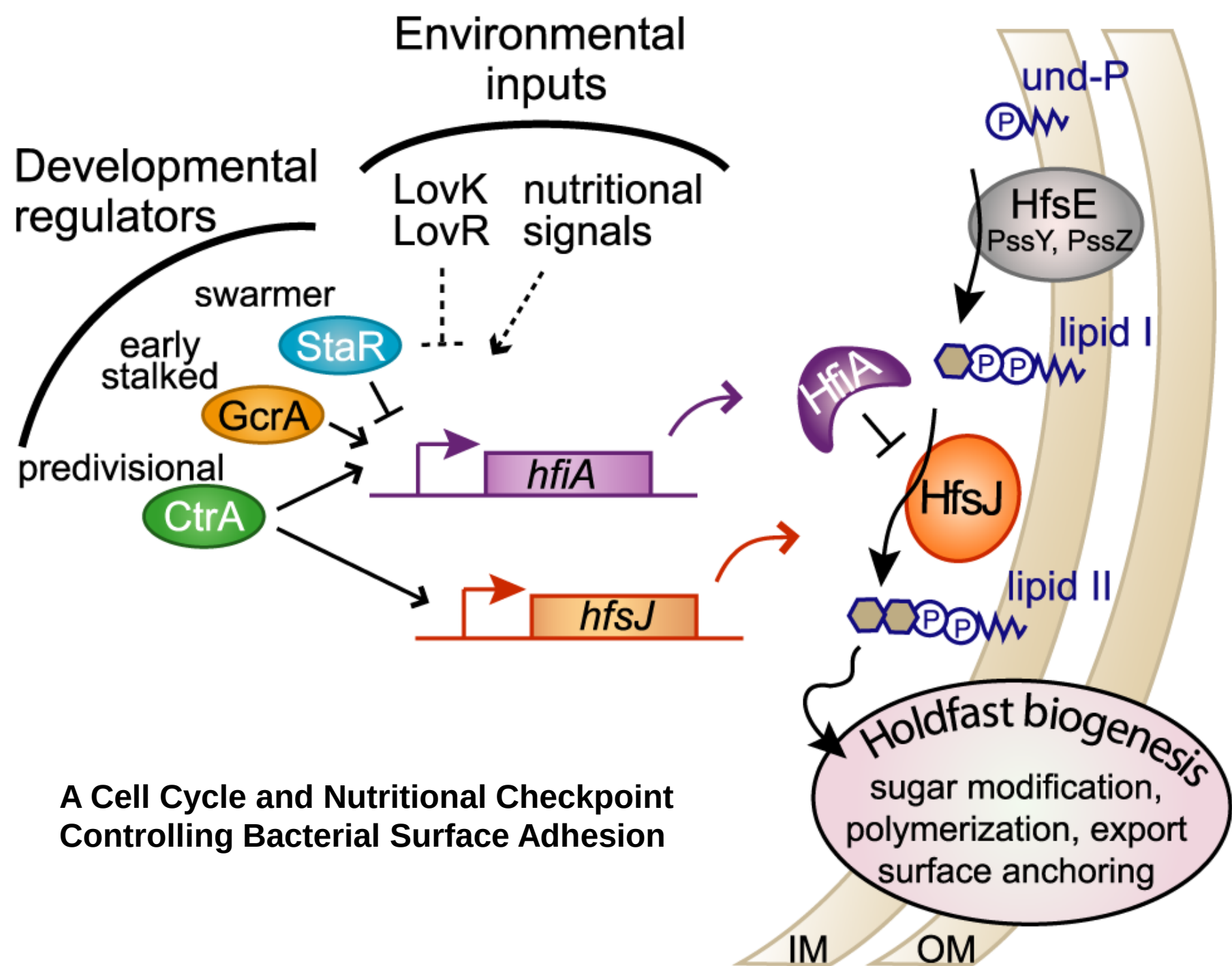


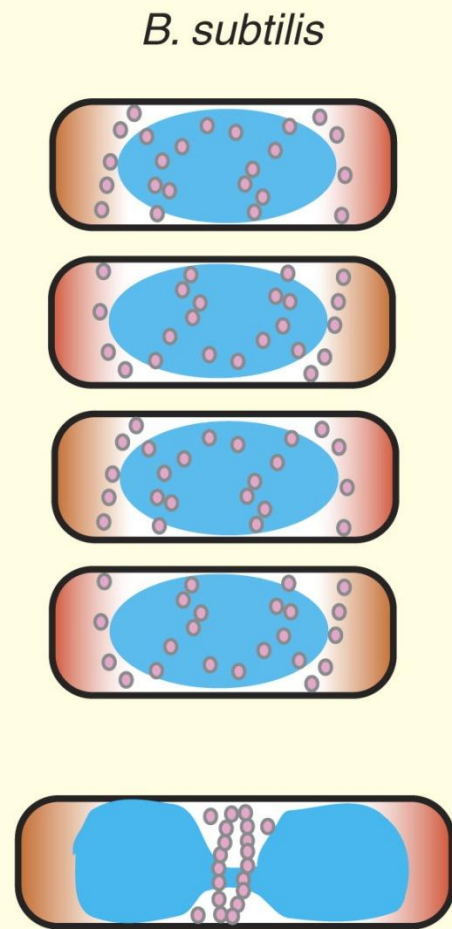
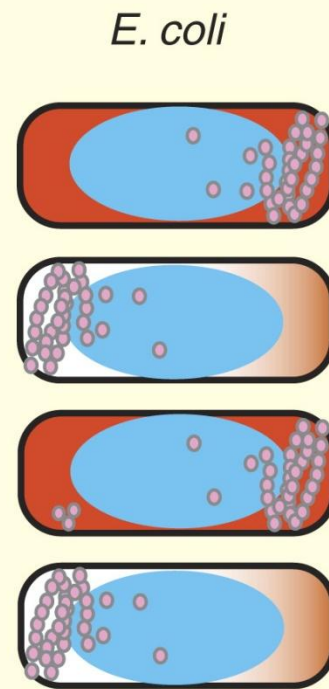
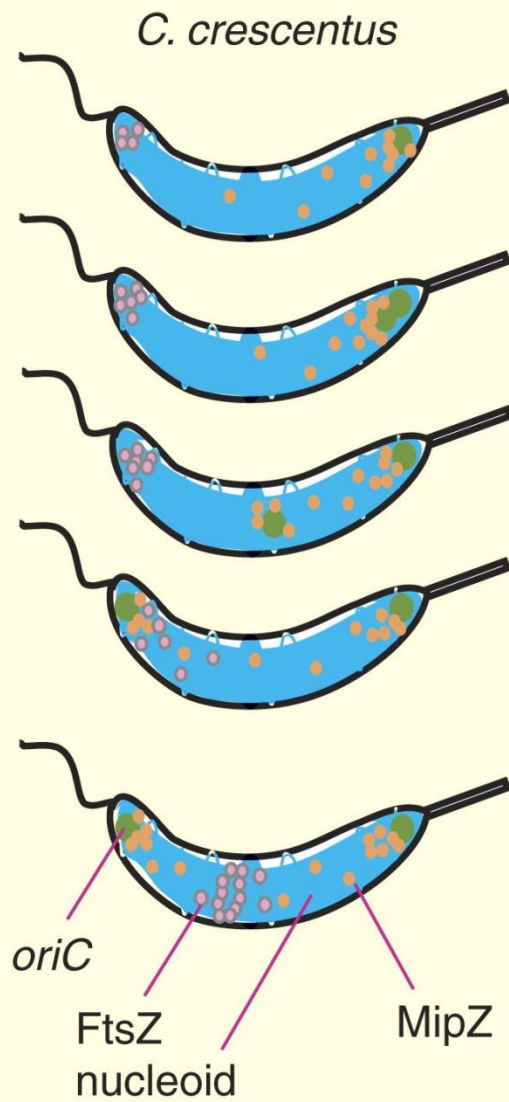
A DNA methylation ratchet governs progression through a bacterial cell cycle, 2007



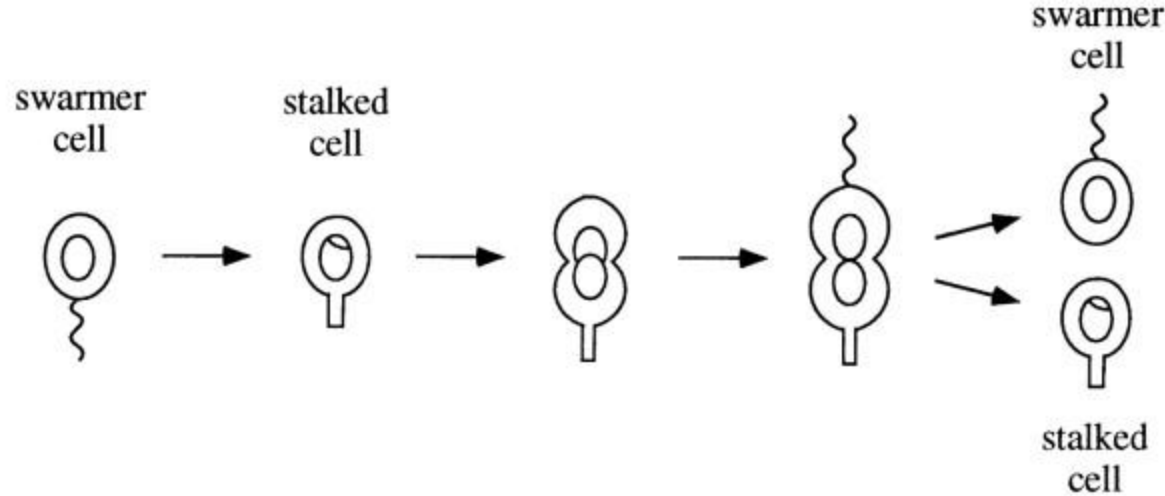


The bacterial SMC (structural maintenance of chromosomes) complex binds nonspecifically to DNA in vitro and forms two discrete subcellular centers in vivo, one in each cell half.



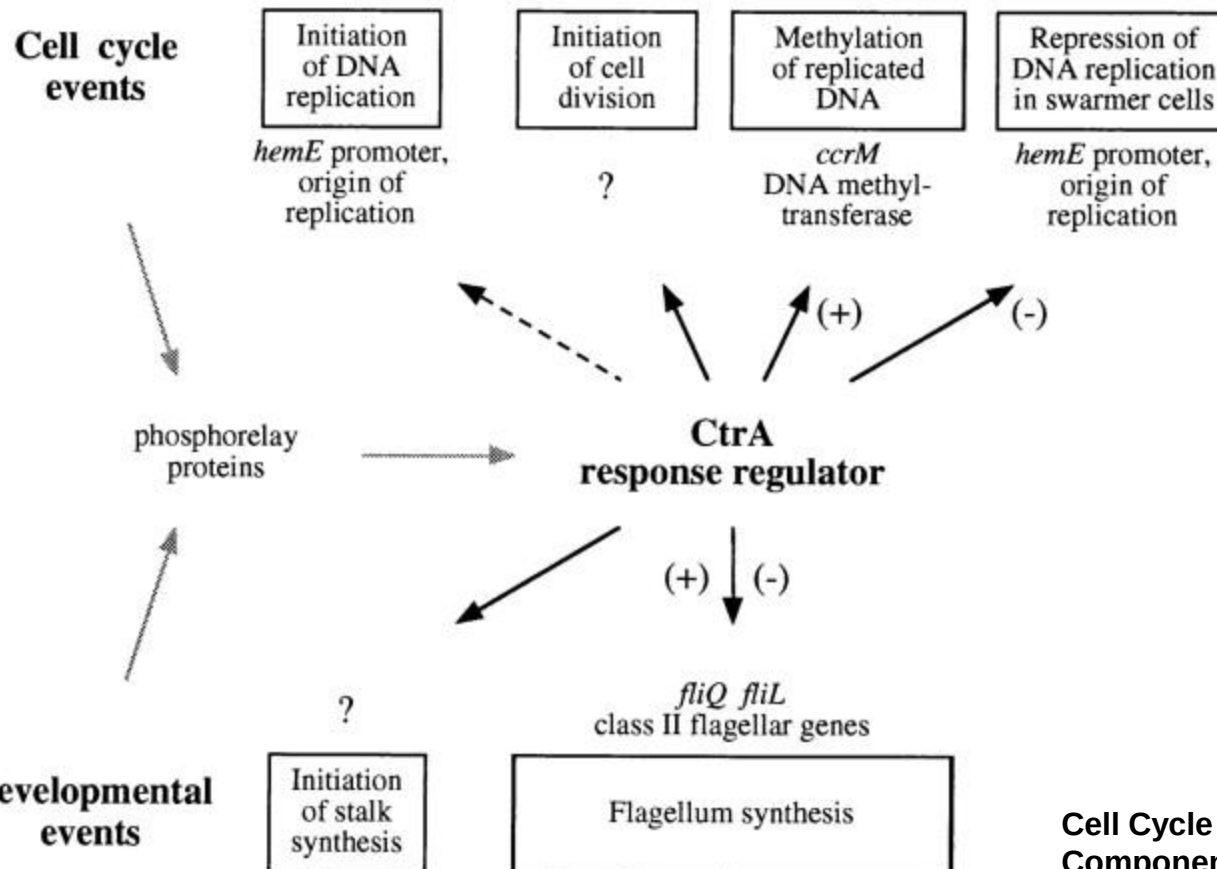


Current Biology

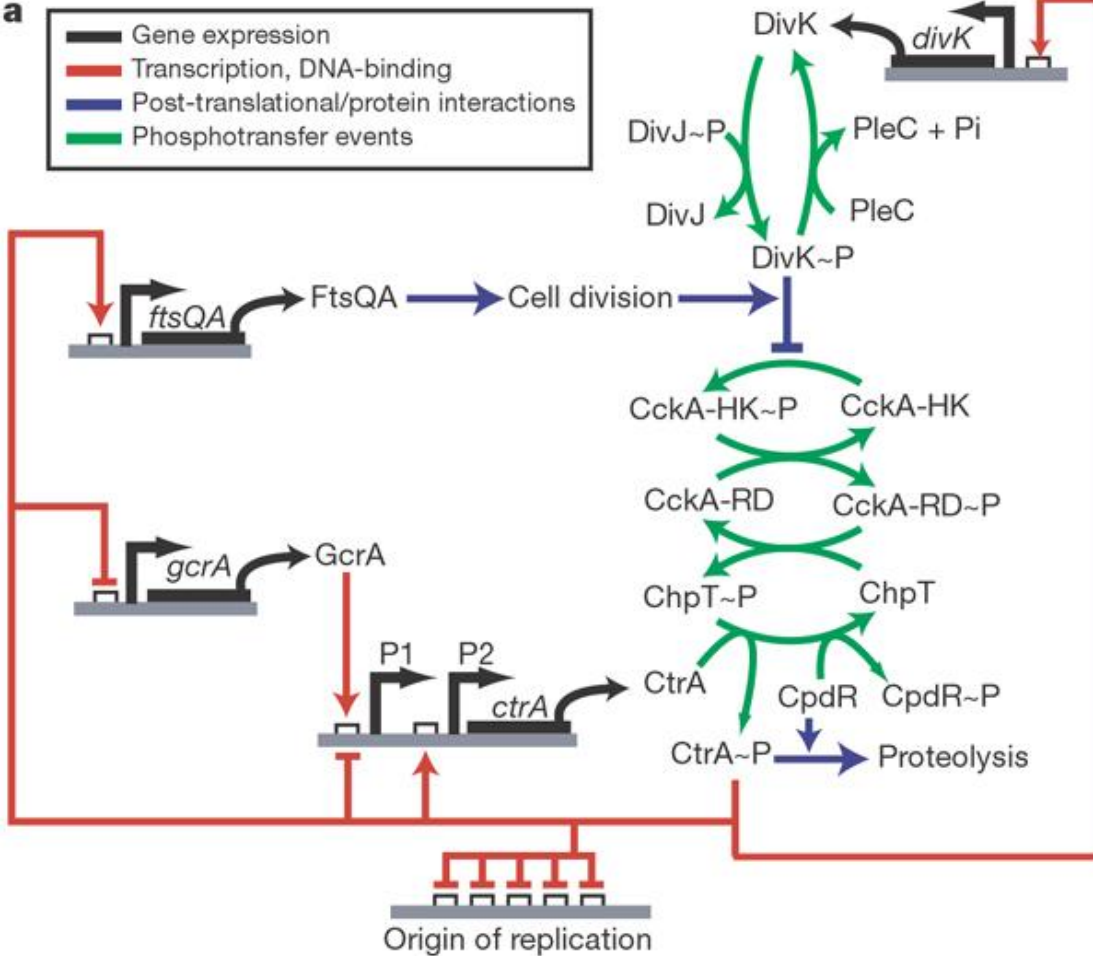


Role of CtrA in the Regulation of the Cell Cycle and Development in Caulobacter

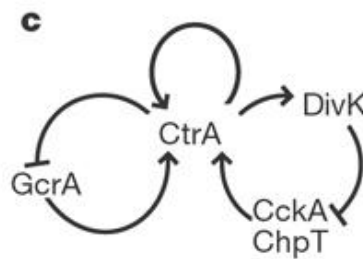
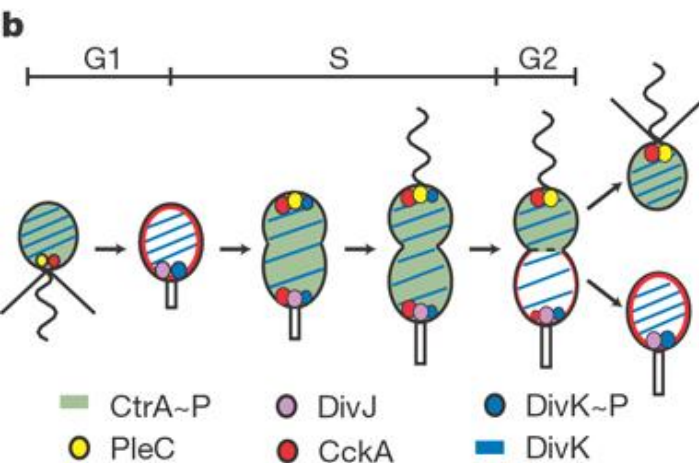
This protein, CtrA, is homologous to response regulator transcription factors and controls transcription from a group of cell cycle-regulated promoters critical for DNA replication, DNA methylation, and flagellar biogenesis. CtrA activity in the cell cycle is controlled both transcriptionally and by phosphorylation. As purified CtrA binds an essential DNA sequence motif found within its target promoters, we propose that CtrA acts in a phosphorelay signal transduction system to control bacterial cell cycle events directly at the transcriptional level.



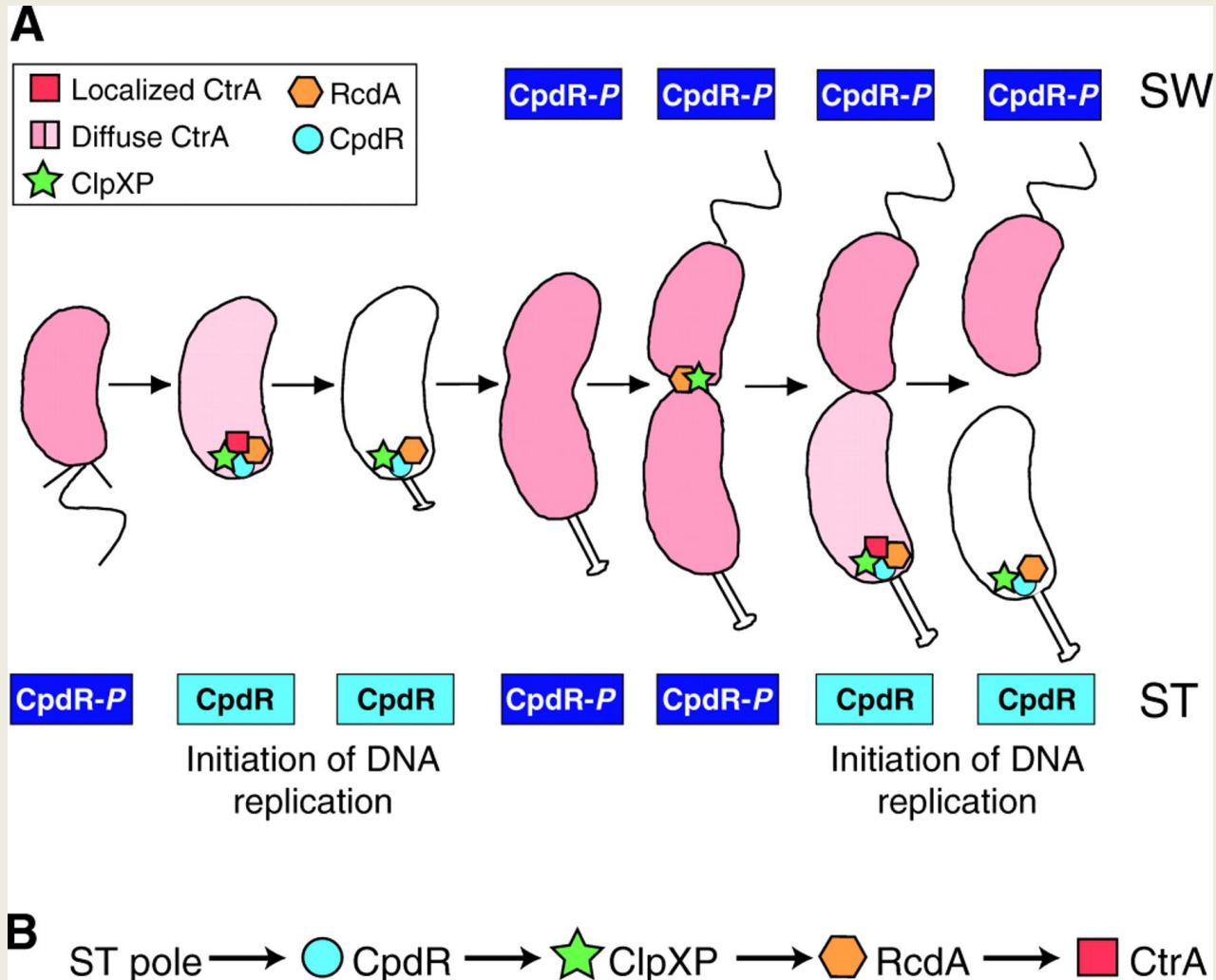
Cell Cycle Control by an Essential Bacterial Two-Component Signal Transduction Protein, 1996



Regulation of the bacterial cell cycle by an integrated genetic circuit, 2006

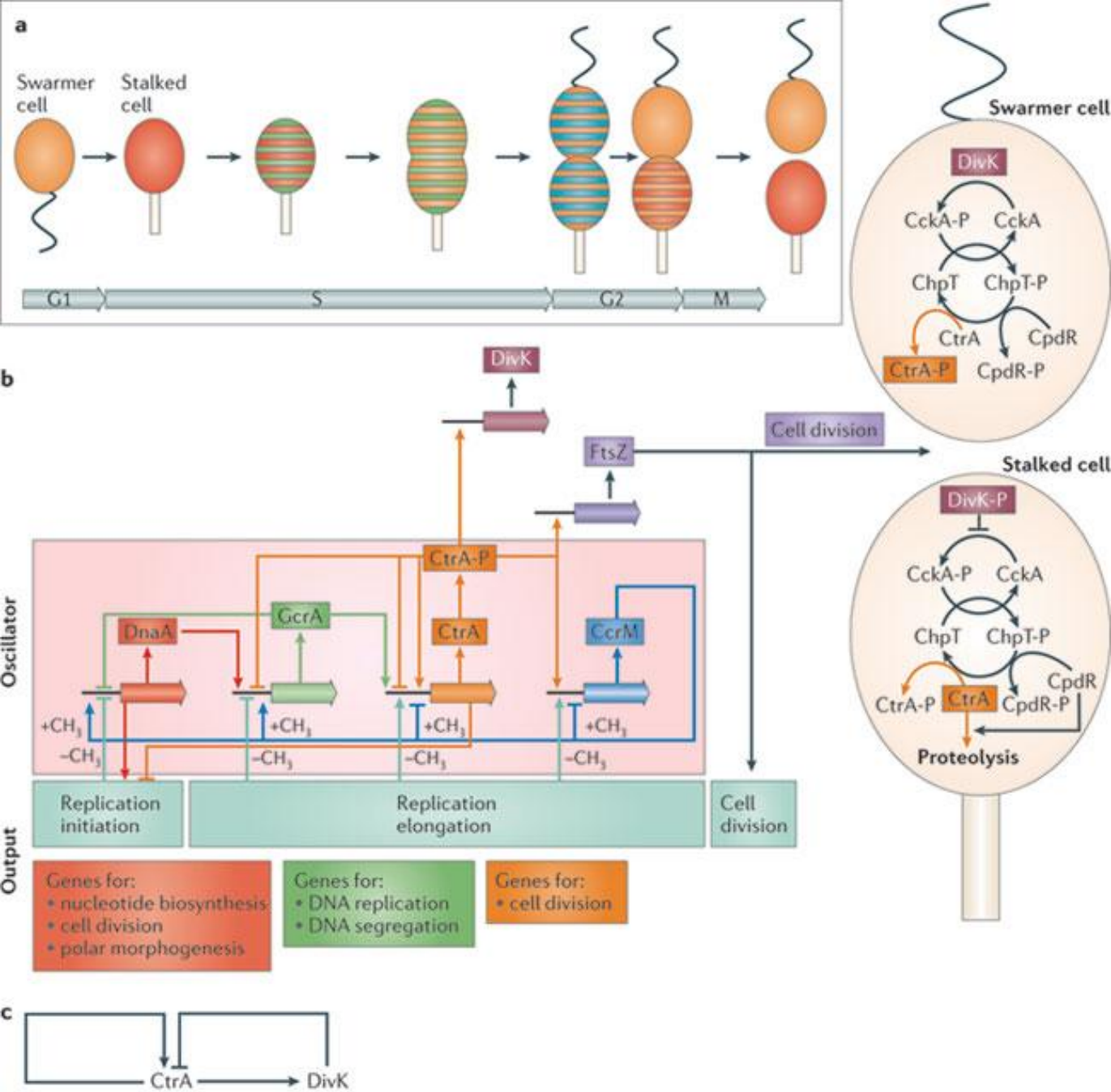


Spatial mechanisms governing proteolysis of CtrA.



Goley E D et al. J Cell Sci 2007;120:3501-3507

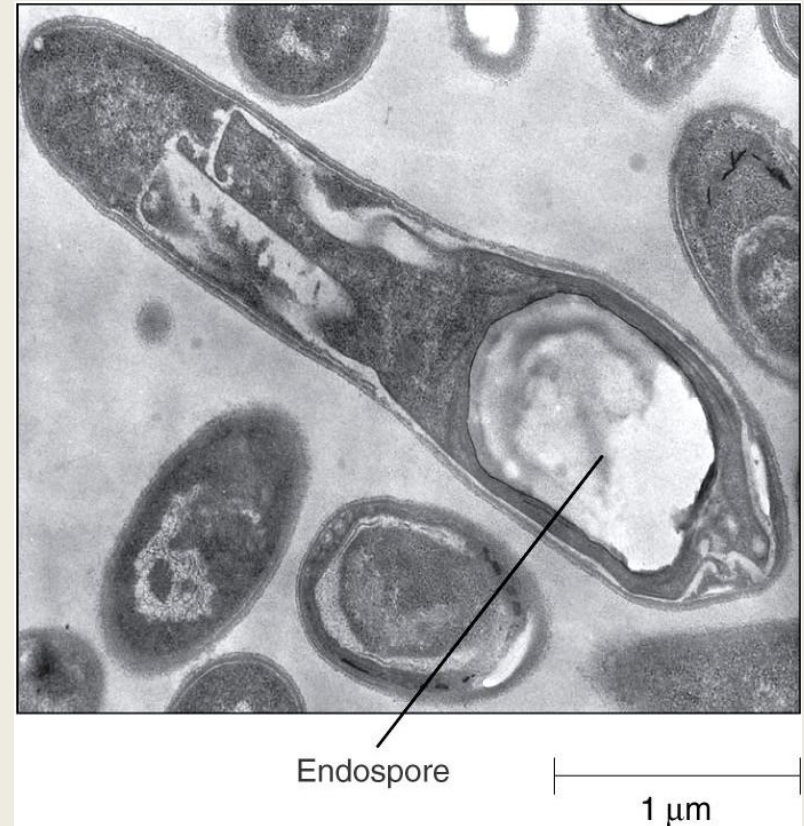
Temporal and spatial oscillations in bacteria, 2011



INTERNAL STRUCTURES

- Endospores

- Dormant cell types
 - Produced through sporulation
 - Theoretically remain dormant for 100 years
- Resistant to damaging conditions
 - Heat, desiccation, chemicals and UV light



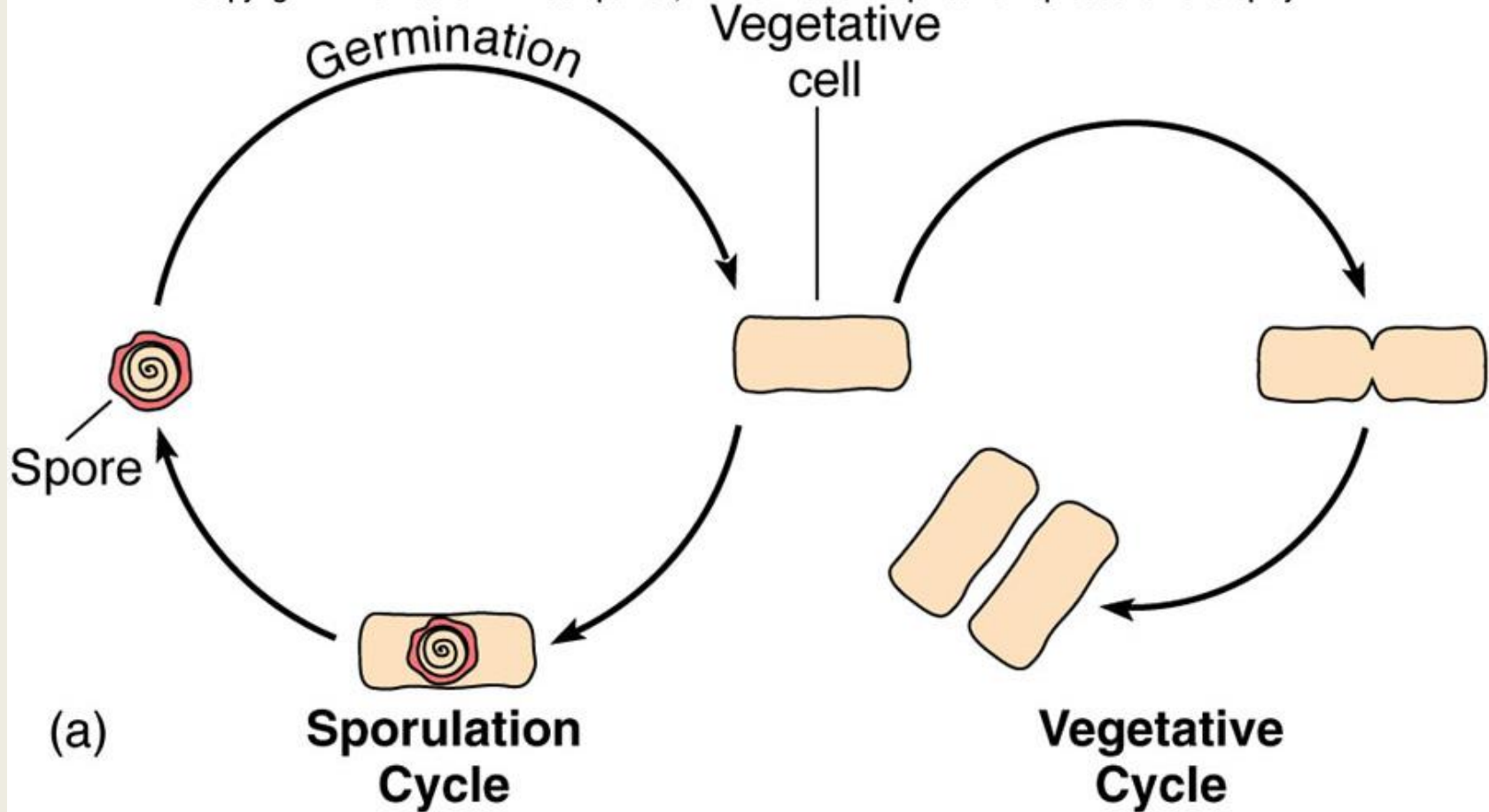
Common bacteria genus that produce endospores include *Clostridium* and *Bacillus*

Table 3.3 *Differences between endospores and vegetative cells*

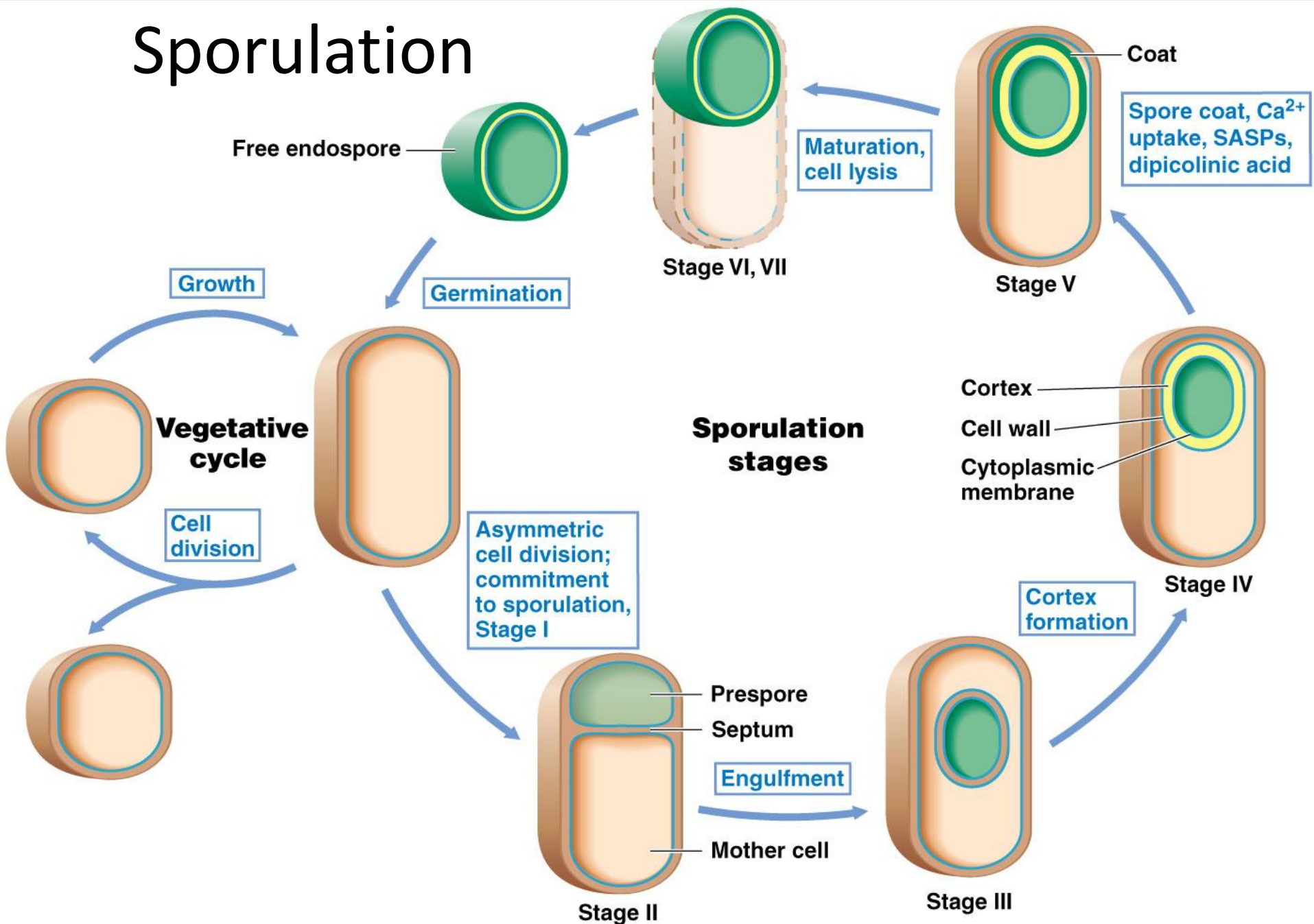
<i>Characteristic</i>	<i>Vegetative cell</i>	<i>Endospore</i>
Microscopic appearance	Nonrefractile	Refractile
Calcium content	Low	High
Dipicolinic acid	Absent	Present
Enzymatic activity	High	Low
Respiration rate	High	Low or absent
Macromolecular synthesis	Present	Absent
Heat resistance	Low	High
Radiation resistance	Low	High
Resistance to chemicals	Low	High
Lysozyme	Sensitive	Resistant
Water content	High, 80–90%	Low, 10–25% in core
Small acid-soluble proteins	Absent	Present

Endospores

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

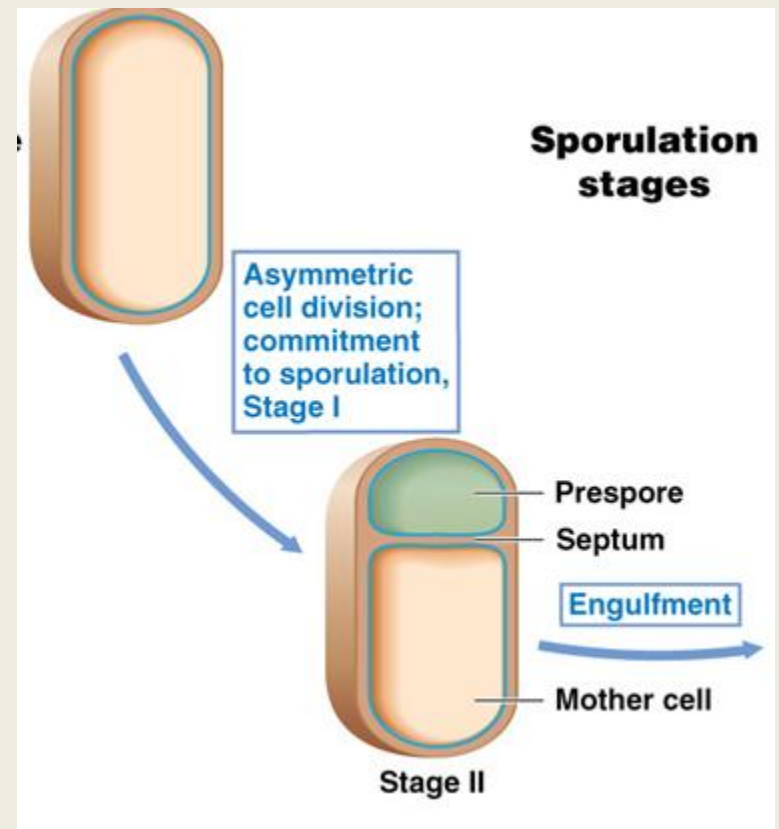


Sporulation



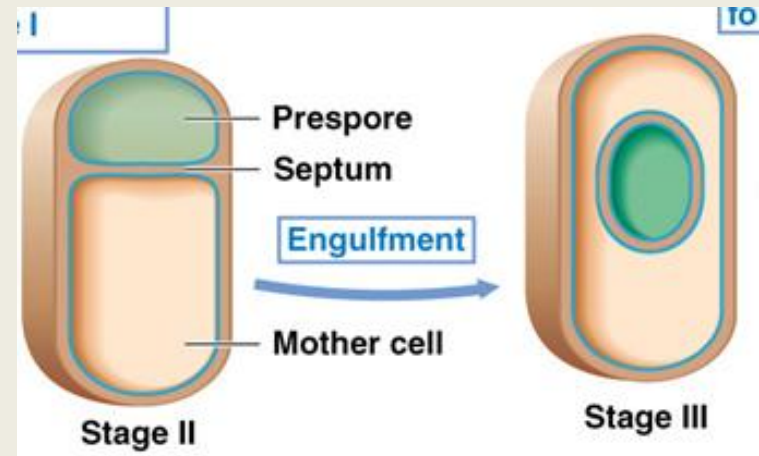
Sporulation stages-stage I-axial filament formation

1. End of log phase
2. Carbon ↓ pH ↓ etc...
3. DNA replication;
asymmetric division;
differential gene
expression in
chromatides
- 4 **Spo genes** activated in big
(mother) cell (σ factors)
5. **Reversible**
6. Chromatides attach to
membrane at poles



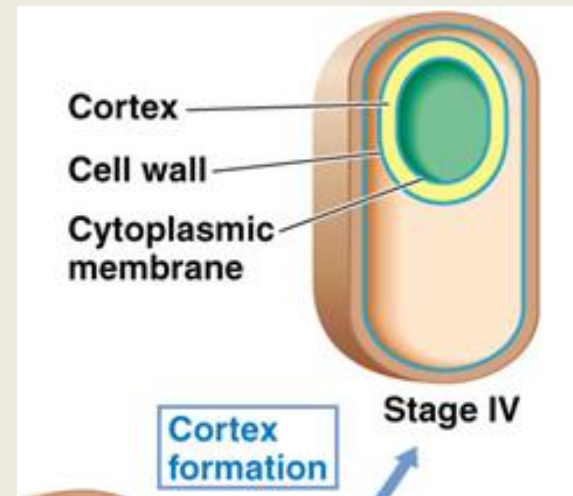
Sporulation stages II & III **Forespore** development

1. Outer forespore membrane
Inner forespore membrane
2. New membrane synthesis
3. DNA trapped in forespore
4. **FtsZ ring** forms at a polar site
5. reversible



Sporulation stage IV- cortex development

1. **Cortex forms** between ifm & ofm
2. ATP levels ↓
3. 3 Phosphoglyceric acid ↑ (3PGA)
4. Refractility develops
5. **Dipicolinic acid (DPA) & calcium** ↑
in forespore
6. Committed

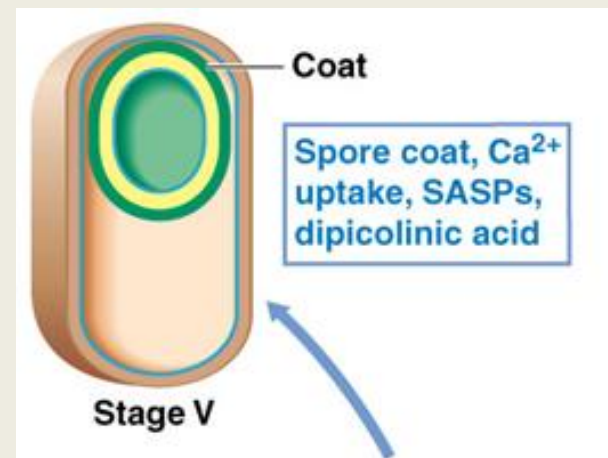
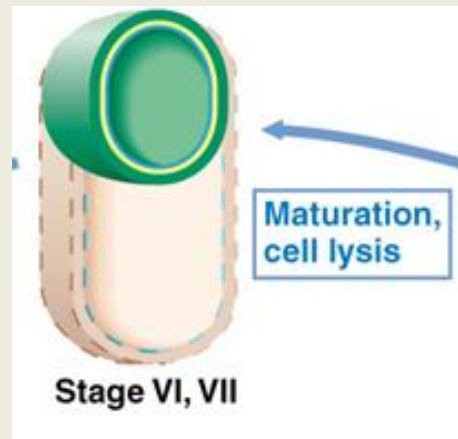


Sporulation Stage **V-coat formation**

1. Refractility complete
2. **Coat proteins made in mother cell**
3. Coats discontinuous & join up

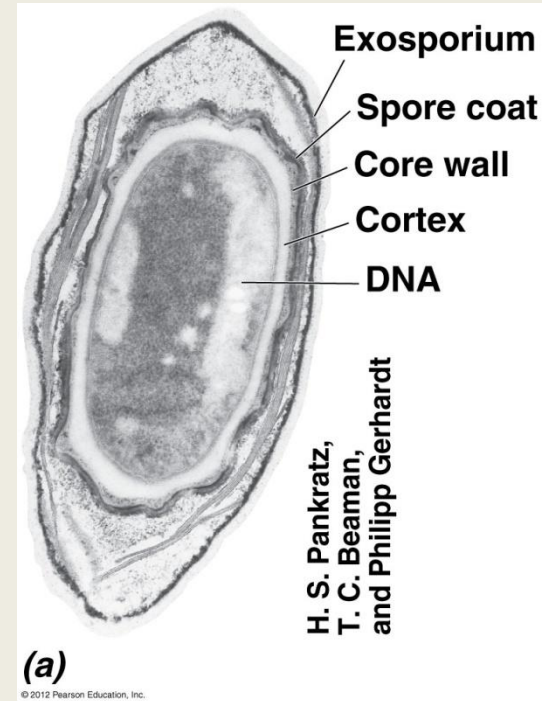
Stage VI

Release of spore - autolysis of mother cell



Spore specific components

1. Inner & outer **coats** (protection): 50% spore volume (slides); 40-60% total dry weight; **Protein** (~60 polypeptides); resistant to chemicals eg 8M urea, 80% phenol; stable disulphide rich proteins
2. **Cortex** (dehydrates the core): peptidoglycan (no teichoic acid); thick 'cell wall like layer'; lightly x linked (7%); maintenance of dormancy? /Hypothesis: Cortex exerts an **osmotic pressure** on the spore core $\Rightarrow$ dehydrating it; cortex has an **osmoregulatory function**; partially dehydrated core (25% water) in equilibrium with a wet cortex (75% water).
3. **Ca : DPA** (Ca wet heat resistance)
4. **SASPS** (multifunctional) binding to DNA $\Uparrow$ wet & dry; ht & UV resistance



3. Accumulation of Ca:DPA

Calcium accumulation

- 2% dry wt in mature spore
- Facilitated diffusion

Dipicolinic acid synthesis (DPA)

- DPA made in mother cell
- pyridine-2,6-dicarboxylic acid
- Ca : DPA present in a 1:1 molar ratio; low free Ca
- Ca linked to ↑ wet heat resistance (mechanism unknown)
but NOT DPA /function of DPA unknown

4. Small acid soluble proteins (SASPS)

Provides resistance to **dry & wet heat, UV,**

- α/β SASPS
- made in developing **forespore**
- 3-8% spore protein
- **DNA binding proteins** (DS DNA)
- changes DNA structure

Germination of spores

Activation (reversible) /Conditioning spores to germinate:
Heat activation (eg 5min at 60°C); Ageing /. Activated
spores $\Rightarrow$ no endogenous metabolism

Germination (irreversible): Ca-dipicolinate and cortex
components disappear; SASPs degrade; Swelling with
H₂O; **NO ATP** until Metabolism - O₂, glycolysis, TCA cycle
etc; Macromolecular synthesis - RNA & protein, DNA,
cell wall...

Cell begins to divide like normal= **Outgrowth** into a new
vegetative cell

→ Resistant dormant spore $\Rightarrow$ sensitive metabolically
active spore: trigger reaction;
150 genes in sporulation (*spo*) & germination (*ger*)

